ANIMAL AND PLANT COMMUNITIES OF THE COASTAL ROCK-PLATFORM AT LONG REEF, NEW SOUTH WALES.

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(Plates vii–xi; three Text-figures.)

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I. *Introduction.*

The rock-platform at Long Reef has long been considered by marine biologists as one of the most productive collecting grounds in the neighbourhood of Sydney. Owing to the nature of the rocks which form the platform, many types of habitat are offered for colonization by marine plants and animals. In consequence, the fauna and flora are exceedingly varied. It was thought, therefore, that it would be of interest to attempt to list the various plants and animals of this area and to find out, as far as possible, what communities existed there. Conditions are such that rock-dwelling and sand-burrowing communities are found, side by side, in the same tidal zone and under similar physical conditions. It is, therefore, possible to make comparisons of these faunas.

The area chosen for this survey forms only a small part of the rock-platform at the western edge of Long Reef, Collaroy, and lies on the open coast about six miles to the north of the mouth of Port Jackson (see Fig. 1). Its exact position is latitude 33° 44′ 30″/S., longitude 151° 19′/E.

Long Reef is exposed to the action of the surf, but the area under study is relatively sheltered from the force of big seas, by the easterly projection of the remainder of the reef and by a number of residual blocks of stone and reefs on its seaward edge (see Pl. x, fig. 23).

As no maps of a scale suitable for use in this work were available, a map was constructed by plane-table survey and proved accurate enough for the purpose of this paper. For ease of reference, the various parts of the reef were given the names which appear on the map. It should be understood, however, that these names are for the author's convenience alone and will not be found on any official map of Long Reef.

* The greater part of the work was carried out while the author was holding a Linnean Macleay Fellowship in Zoology.

As the work continued, it became apparent that the type of survey being attempted could more satisfactorily have been carried out by a team of workers, since taxonomic problems alone would occupy much time. It has been carried on, nevertheless, in the hope that this beginning may be of use to some future worker, who wishes to carry on a more detailed investigation.

In a work of this type, the author is dependent on some help from taxonomic workers and other specialists. Apart from acknowledgements made in the body of the paper, the author is indebted to Professor W. J. Dakin, D.Sc., who first suggested that the selected area should be studied; to the members of the staff of the Department of Zoology, University of Sydney, who accompanied the writer on many occasions to the reef and assisted with the work; to Miss G. Burns and Mr. G. C. Clutton, who processed several illustrations, and to those workers who lent photographs; to the late Mr. C. C. A. Monro of the British Museum of Natural History (Polychaeta), Dr. H. Thompson of the Council for Scientific and Industrial Research (Ascidians), the late Mr. A. L. Tonnoir (Chironomidae), Mr. K. Sheard of the South Australian Museum (Amphipoda), Professor T. Harvey Johnston of the University of Adelaide (Nematoda), Dr. E. A. Briggs of the University of Sydney (Coelenterata), Mr. M. Ward, Honorary Zoologist of the Australian Museum (Crustacea), and to the following members of the staff of the Australian Museum who were especially helpful: Dr. A. B. Walkom, who checked the manuscript, Miss J. Allan (Mollusca), Mr. T. Iredale (Mollusca), Mr. J. R. Kinghorn (Reptiles), Mr. A. Livingstone (Echinodermata), Mr. F. McNeill (Crustacea) and Mr. G. Whitley (Fish). In addition to help with taxonomic work, Mr. F. McNeill kindly read and checked the manuscript.

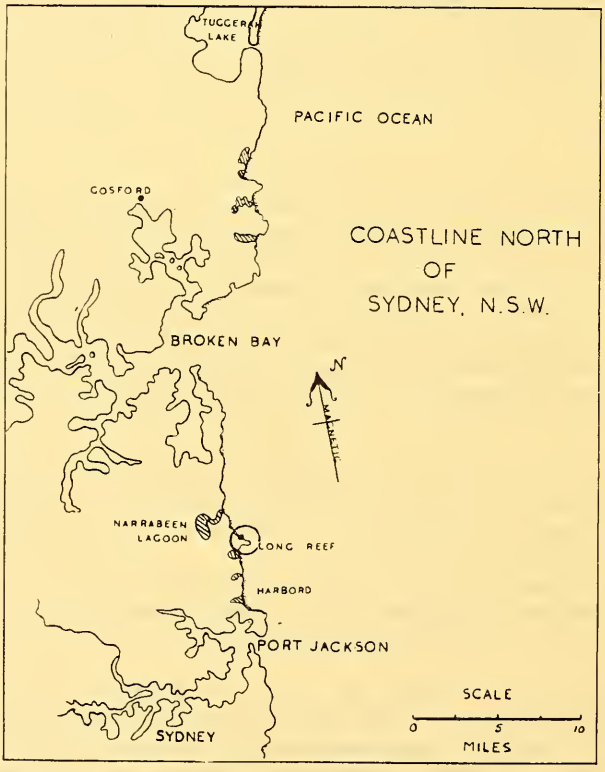

Fig. 1.—A general map of the coastal area between Sydney and Tuggerah Lakes. The area under special study appears as a small, black dot, enclosed by the circle.

II. Extent and Position of the Area and the Nature of the Substratum.*

An area, approximately two hundred and forty yards long at its landward limit and one hundred and seventy yards wide, was chosen and mapped for study. The eastern and western portions of the area are comparatively flat rock-platforms called respectively "Chocolate Shale Point" and "Grey Shale Point" (Plate vii). "Grey Shale Point" has a rougher surface than "Chocolate Shale Point" (Pl. x, fig. 23). Between these two rock-platforms is a small, sheltered bay, the bottom of which is composed of layers of small boulders with occasional pockets of sand among them. It is referred to as "Stony Bay" and the nature of the substratum may be seen in Plate viii, figures 1 and 2. The sandy beach shown on the map (Plate vii) is not a constant feature of the reef, since its size and extent alter frequently under the influence of winds and storms. The map indicates the chief features of the beach when normal conditions of tide and weather have prevailed for some months.

The area lies at the north-western end of Long Reef (Fig. 1) and is greatly sheltered by the eastward extension of the main reef from the heaviest seas which come, as a rule, from a general southerly direction.

Rock-platforms to the south, in the vicinity of Long Reef, are of Hawkesbury Sandstone—the middle division of the Triassic System—and, as a rule, they slope steeply to the sea as, for example, at Harbord. Long Reef itself and the neighbouring rock-platforms to the north are composed of rocks from the upper beds of the Narrabeen Series which is the lowest division of the Triassic System.† The reef is flat with a sudden slope or nearly vertical drop at the seaward edge to the low-water mark, except where tiny bays and inlets have been eroded by wave action.‡ The rocks composing the reef comprise grey tuffs, associated with chocolate shales of several types, and argillaceous tuffs and shales and shale breccia. The rock-platform is believed to have been formed during early Pleistocene times, when it was cut out by the action of the waves, at a time when the sea-level was approximately sixteen feet higher than its present level. Neighbouring rocky headlands have rock-platforms which were eroded at the same time, but the nature of the rocks at Long Reef and, particularly, their subsequent erosion has caused the area to differ from the majority of such reefs, for the strata at Long Reef show a slight degree of crumpling and this has brought some softer, lower layers of rock to the surface.

The area studied was originally occupied by an anticlinal structure plunging at a low angle towards the south-west. The axis of this anticline is indicated on the map (Plate vii) by the dotted line F–G, and the extent of the outcrops of the various rocks on either side of the axis is roughly indicated as well. The surface of the rock-platform on either side of the anticline is formed of hard calcareous and tuffaceous chocolate shales, while beds of argillaceous tuffs and shales, massive chocolate shales, and shale breccias are brought to the surface by the anticlinal structure. The argillaceous tuffs and shales and the shale breccias are softer and more susceptible to the mechanical erosion of wave action and, as a result, the sea has removed much of them and formed bays, a larger one, "Stony Bay", on the eastern side of the anticline, and a smaller one, "Little Bay", with pools behind it, on the western side of the anticline. "Stony Bay" is the larger, owing to the fact that the north-eastern side of the anticline is more exposed to the sea and wave action than the north-western side. A bed of comparatively hard massive chocolate shale, which occupies a lower horizon than the soft, tuffaceous shale, also outcrops along either side of the anticline, and it is due to the exposure of this band of chocolate shale that the small outlying islands and reefs have developed. The islands represent residual blocks of shale which have withstood the action of the waves, whilst the reefs, seen at low tides, represent blocks of shale in a more advanced stage of disintegration. The two bays were probably

* The original outline map on which those used in this paper are based was drawn by plane-table survey by Miss S. Swain, B.Sc., Mr. L. Cane, B.Sc., and Mr. W. Allen, B.Sc., who, at the time, were students in the Department of Geography, University of Sydney.

† A description of the geology of this district is given by Alma G. Culey (1932).

‡ See sections across this part of the reef, Figure 2.

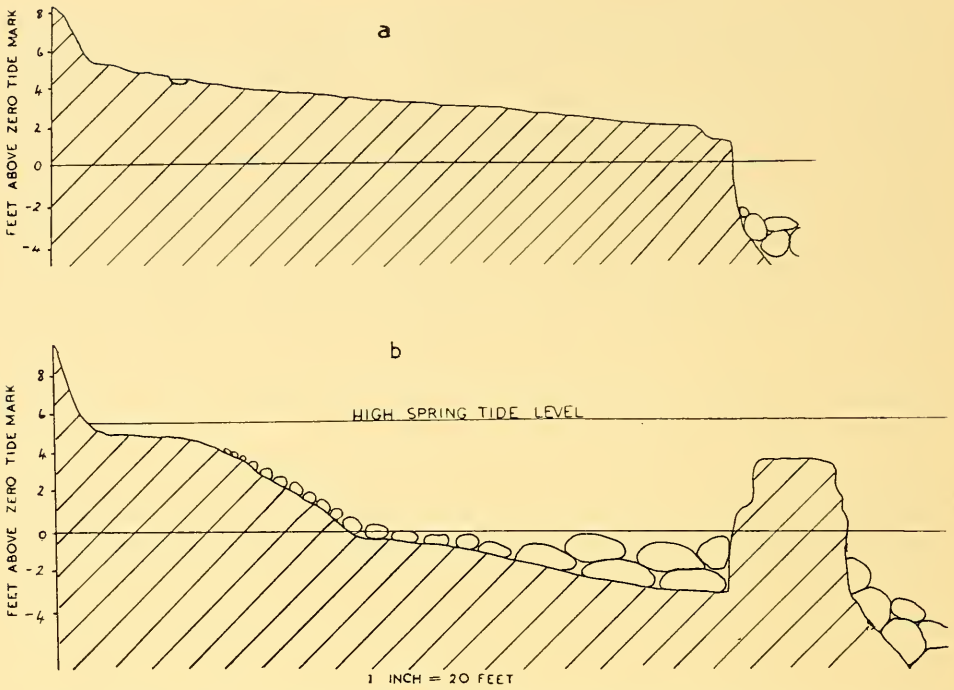

Fig. 2.—A, Section through "Chocolate Shale Point" along the line running through the points A and B in Plate vii*a*. Note the gradual slope across rock-platform with the sudden vertical drop at the seaward limit. B, Section through "Stony Bay" along the line running through the points C and D in Plate vii*a*. The slope is more gradual in the "Bay". The boulders are not drawn strictly to scale.

formed in late Pleistocene or Recent times and are still undergoing development.* The floor of "Stony Bay" and an area around the outer edge of the rock-platform are strewn with stones and small boulders, the debris of erosive processes. In "Stony Bay" they are small inshore and become gradually larger as one proceeds out to sea. Plate viii, figure 1, shows a close view of the stones in the inshore area of the bay and Plate viii, figure 2, shows the size of the stones further out to sea where they are considerably larger. It is largely due to the presence of these stones that the variety of the fauna is so great at Long Reef, since they offer a great degree of shelter and so great an area for attachment for encrusting and clinging forms.

III. Environmental Factors.

A good general account of the sea currents, tides and other environmental factors for the coastal waters near Sydney has been given by Hedley (1915) and the following data are added only as an amplification of his data or because they are more strictly applicable to the particular area.

1. *Wind: Its Effect on Wave-size and as a Desiccating Agent.*

Long Reef is fairly exposed, and the area studied is sheltered by the easterly projection of the remainder of the reef from the effects of heavy seas, but not from other wind effects, e.g., desiccation. As a rule, the size of the waves on this part of the reef is not great and it is only during storms that it is subjected to severe wave action. A high headland behind the rocks acts, to a limited extent, as a breakwind. The prevailing winds vary with the season. In the warmer months (October to February) the wind blows mainly from the north-east or east, whilst the south wind, which blows

* The author's thanks are due to Mr. J. A. Dulhunty, B.Sc., Linnean Macleay Fellow of the Society, who visited the reef and gave advice on the geology of the particular area under consideration.

mainly at night and is the next most frequent wind, brings the characteristic cool change at night or in the late afternoon. During the colder months (April to October) the wind blows mainly from the west. The effect of the wind on the size of the waves is marked at Long Reef, westerly winds tending to flatten out the sea and to blow the water off-shore. It is thus generally during the winter that it is easiest to reach the lower parts of the reef for collecting purposes.

Fairly recently a hot wind which reached, at times, a velocity of seventy-five miles an hour in Sydney, happened to coincide with a low tide on the reef and caused a marked amount of damage to the inhabitants of the reef. This damage was not, however, as severe as might have been expected. Although the desiccating effects of such a hot, dry wind must have been severe, only a few animals had succumbed and among the algae only those plants from the higher parts of the reef had died. Even in this region the plants which had perished were mostly those from the borders of large expanses of weeds. *Hormosira* and *Sargassum* suffered most in this way, since both these species occur on the upper surfaces of the rock-platform and had in consequence been subjected to desiccation for some hours continuously during the gale.

2. *Freshwater on the Reef—Rainfall.*

There is no permanent drainage of freshwater over the reef but after rain, a considerable amount of water seeps out from the hill behind and drains out to sea over the rocks. The incoming tide removes such water and it cannot lie, even in pools, on any part of the reef, for more than nine hours at a stretch (generally less) and has, therefore, very little effect on the plants and animals of the area.

3. *Temperatures.*

The average air shade temperature at Sydney over the three years (1936–1938) was 17·3°C. The maximum shade temperature lies, as a rule, round about 36°C., whilst the minimum lies near 2°C. to 3°C.

A graph, showing the shade and sea temperatures recorded during one year at Long Reef, is given in Text-figure 3. The water temperatures were taken at a station on the edge of the reef where the water circulates freely. All these temperatures were taken in the daytime and it is likely that slightly colder conditions obtain on the reef, at nights, when a cold wind blows and cools the reef, but it has not been practicable to record them.

As far as can be ascertained, during recent years, regular readings of the temperatures of the sea-water close to a rock-platform have not been taken in the Sydney district. Several workers have made regular readings of the temperature of the waters of Port Jackson. Dakin and Colefax (1935) give a range of temperatures for a station situated four miles out to sea, east of North Head. Hedley also gives some figures for readings in Port Jackson, and Iredale, Johnson and McNeill (1932) give temperatures for a number of stations. None of these temperature ranges, however, can be considered to be strictly applicable at Long Reef.

Temperatures were taken on every visit to the reef for the period of a year and a half and the figures thus obtained are the ones used in the graph (Text-figure 3). The range of sea temperatures was 12·4 Centigrade degrees, the maximum being 24·4°C. (recorded in March), and the minimum 12°C. (recorded in July). Since absolutely regular readings were not taken, and since the intervals between readings were often over a month, it is likely that the true range of temperatures is even greater than that given above. The following table summarizes the findings of various workers as to the temperatures of the sea in the neighbourhood of Sydney.

Sea Temperatures at Various Stations near Sydney, N.S.W.

Locality	Long Reef.	4 miles E. of N. Head.	Sydney Harbour.	
Observer	E. Pope.	Dakin and Colefax.	Hedley.	Iredale, etc.
Range of Temperature	12·4°C.	7·0°C.	9·22°C.	10·7°C.
Maximum Temperature	24·4°C.	23·5°C.	22·22°C.	24·5°C.
Minimum Temperature	12·0°C.	16·5°C.	13·0°C.	13·8°C.
Number of Years of Observation	1·5	3	10	3

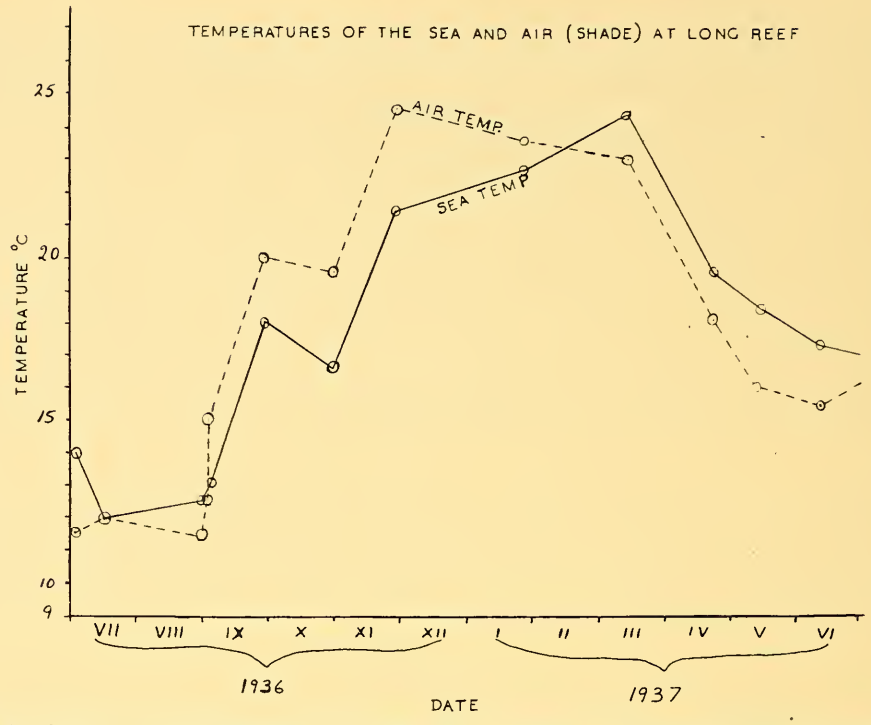

Fig. 3.—Graph of the temperatures of the sea and air (shade) at Long Reef. Roman numerals are used to designate the months of the year. The graph represents the readings for one year.

From this table it may be seen that the sea-water temperatures at Long Reef show a greater range than do those of the neighbouring ocean or the waters of Port Jackson. Also the maximum and minimum temperatures exceed those recorded for the other stations, by reason of the fact that the temperature of the rock-platform influences that of the sea-water above it. During low tides, the hot summer sun or the cold winds of the winter's night can change the temperature of the rocks considerably, and with the return of the tidal water, over the reef, there is an adjustment between the temperature of the water and that of the rocks. This would account for the wider range in temperatures of the sea-water on the reef. This range in temperatures affects the creatures of the reef but little, since they must needs be eurythermal in order to exist there, for they are subjected to considerable extremes of temperature during low tides. However, the seasonal change of temperature does influence the fauna, for regular, though limited, migrations of certain types take place at set seasons of the year. Some creatures move from a seaward part of the reef inshore during the hot summer months. For instance, the sea-urchin, *Heliocidaris erythrogramma*, is found at a slightly lower level on the reef during the colder part of the year, and returns to its former station when warmer conditions are re-established. Certain molluscs—some nudibranchs and sea-hares—visit the reef to lay their egg-strings during the warmer season and, in addition to these regular visitors, stragglers from warmer localities are frequently found at Long Reef, brought there by the south-flowing, warm Notonectian current which flows in towards the coast in the summer-time.

4. *Tides.*

The tidal range is about six feet seven inches, and the tidal information given for Port Jackson applies, as a general rule, at Long Reef,* except that the tide is a few

* It should be noted that the height of the tide is measured locally from an arbitrarily chosen zero mark on the official tide gauge at Fort Denison in Port Jackson. This mark approximates to the average level of the low water mark for ordinary low spring tides. Very low spring tides fall below this mark and are referred to as "minus tides", being marked on the local tide charts as tides of "–7" or "–4" inches, etc.

minutes earlier at the reef. The high and low spring tide levels, marked on the map (Plate vii*a*), represent those of a spring tide whose range was from five feet four inches at high tide to minus four inches at low tide.

A low neap tide uncovers most of the two flat rock-platforms and a narrow area of "Stony Bay", chiefly at the eastern and southern limits of the stony area, while a high spring tide of moderate amplitude covers the whole area except the sides and the tops of a few rocks, marked on the map (Plate vii*a*), and an area of boulders on the inshore edge of the sandy beach.

5. *Composition of the Sea-water.*

The seasonal and chemical changes in the composition of the ocean waters in this neighbourhood have been dealt with by Dakin and Colefax (1935), who analysed water samples from a station four miles east of North Head (Sydney). When analyses of samples from Long Reef were made, they were found to correspond closely with the results of these two authors. The findings of these authors may, therefore, be taken as applying at Long Reef since no freshwater enters the ocean in this neighbourhood. At low tide, several large, shallow pools (marked on the maps as permanent pools) are cut off from the circulating waters and, as would be expected, their chemical composition, after some hours of severance from the sea, differs from that of the surrounding water on the edge of the reef. The following figures† summarize the differences in composition of water samples from these two stations. Such differences are due, in part, to evaporation and, in part, to chemical changes brought about by the metabolic activities of the animals of the pools.

	Open Sea.	Pool on "Grey Shale Point".
Temperature	21·4°C.	30·5°C.
Salinity	34·91‰	35·75‰
PO_4 Phosphorus ..	20γ/m³	32γ/m³
NO_3 Nitrogen ..	19γ/m³	30γ/m³
NO_2 Nitrogen ..	0γ/m³	1γ/m³
pH‡	8·4	8·3

Since the faunas in the pools and in corresponding positions on the edge of the reef, where the water circulates freely, are not significantly different, one may infer that the chemical differences in the water from these two situations are not great enough to affect the animals, or that the conditions obtain for too short a time to exercise any effect, since the incoming tide brings in unpolluted sea-water.

IV. Terms and Method of Presentation.

The area of the shore studied showed three horizontal regions—the *supra-littoral*, the *littoral or tidal* and a narrow strip representing the upper part of the sub-littoral called the *sub-littoral fringe*. The *supra-littoral* is taken to include those parts of the shore which lie above the limit of the average high spring tides and are consequently submerged only by the higher spring tides or by waves during stormy or windy weather. The term *littoral or tidal* is used to indicate the area which extends from the lower limit of the supra-littoral down to the limit of the average low neap tides. Below the littoral part of the shore is a narrow belt which is exposed only when low spring tides coincide with calm weather or with off-shore winds. This part is termed the *sub-littoral fringe* by Bright (1938) and his term has been adopted. Apart from these horizontal divisions of the shore life, animals may occur in three definite positions with regard to the substratum, namely, on the substratum, in the substratum and, where stones form the shore, beneath the substratum. King and Russell (1908) drew attention to the importance of the fauna from the lower sides of stones as a separate division of any community. Torsten Gislén (1930) assigns definite names to these divisions of the

† The author is indebted to Mr. D. Rochford, B.Sc., for analysis of the various samples of sea-water from Long Reef.

‡ The high pH reading is probably associated with the presence of large quantities of algae on the rocks where the samples were taken.

fauna, namely, "Epibiose", "Endobiose" and "Hypobiose". While it is not intended to adopt these three terms, since they merely add a number of unnecessary technical names which may be omitted without causing confusion, it is nevertheless interesting to bear his definitions in mind and to see how far they fit in with the findings at Long Reef. He defines "Epibiose" as a population of plants or animals which occurs entirely above the bottom surface or has only its anchoring organs embedded in it. "Hypobiose" he defines as a population which occurs in preformed holes, or in free water on the under side of stones. "Endobiose" is defined as a population buried or bored into the substratum, of which only a few isolated members appear above the bottom surface. As a rule the members of the endobiose feed on the animals also buried in the substratum, that is, they correspond to Peterson's "infauna". As would be expected, some of the species of the epiboise occur also in the hypobiose, but, as a general rule, the hypobiose includes many forms not found in the epibiose. The distinction between the two communities is, therefore, quite clear. The hypobiose is really only a specialized form of the epibiose and the life-form of its inhabitants and their feeding habits are similar. The main differences between the animals of these two groups are that those from the upper surfaces of the rocks are better adapted to withstand exposure to heat, desiccation, light and wave action than the related forms from the more sheltered positions under the rocks.

Many of the animals from the lower surfaces of rocks are negatively phototrophic for, when the surface of the rock to which they are clinging is turned uppermost (even though it remain submerged), they crawl hastily round to the new lower surface to escape the light. Also, the structure of the animals from this habitat is, as a general rule, more delicate than that of the animals from the upper, exposed surface. These generalizations apply at Long Reef, as will be readily realized when the more detailed description of the faunas is given. Another observed difference between the two faunas is that the rate of movement is often faster in the members of the community beneath rocks than in similar forms from the upper surface.

Special mention must be made of the part of the reef designated as "Stony Bay" (Plate vii), since it possesses an exceedingly complex fauna. It is essentially a mosaic of two types of biotic communities, since it contains fragments of a sandy beach substratum and of the rocky reef substratum—the latter in the form of numerous smallish boulders which have not only the normal fauna usually associated with the upper surfaces of rock-platforms on the open coast but also an extensive fauna on their sheltered under surfaces. These two communities may thus be compared side by side in identical conditions as regards the amount of time during which they are exposed by the tide and the physical and chemical conditions of the water which bathes them. Plate xi, figure 29, shows part of this mosaic in "Stony Bay". The light patches are sand and the areas where algae are seen represent the upper sides of stones to which the seaweeds are clinging.

In this paper each horizontal division of the shore is described in turn—the supra-littoral, the littoral and the sub-littoral fringe, in that order. In describing each of these zones, first those parts of the reef which belong to the particular zone in question are enumerated. This section is followed by a brief account of the plants in the area. Next, the fauna of the area is dealt with. Inhabitants of the rocky substratum are described first and differentiation is made between those living on the upper and those from the lower surfaces of rocks—the two divisions being dealt with separately. Next, the inhabitants of the sand substratum are described and this section is followed by descriptions of any other type of community or odd group of animals which may be found in that area. The setting out of descriptions of communities in this way greatly facilitates comparisons of the faunas from different levels of the reef.

V. The Supra-littoral.

It is a matter for regret that, in the area under special observation, only a few small scattered places remain above the limit of the average high spring tides. These are submerged during high spring tides or during storms, but nowhere do they extend to any

considerable height above the upper limits of the tide. As a result, a typical, fully-developed, supra-littoral plant and animal community is not found there.

For the great part of its length, the landward edge of the reef is bordered by the steeply-sloping hillside, bounding the local golf course. Since the hillside is made up of soft clays and shales which constantly crumble, it is not a suitable substratum for the development of normal supra-littoral communities either of the type found on a rocky substratum or of the type from a sandy substratum. The supra-littoral is shown in Plate vii*a* as areas which are 5 feet 4 inches or more above zero tide mark. In order, therefore, to study the fauna and flora, all the small scattered patches must be examined and the observations pieced together, like the component parts of a jig-saw puzzle. Even then a complete picture is not obtained, for only the lower reaches of the supra-littoral are represented. One has to turn to other areas of the reef to complete the study of the higher parts of this particular community.

A. PLANTS OF THE SUPRA-LITTORAL.

On the rock surfaces there is practically no growth of algae visible to the unaided eye, except in a few tiny pools where the fine, green filaments of *Ectocarpus confervoides* or *Pylaiella littoralis* are found. These growths alone could hardly furnish an adequate food supply for the animals which inhabit the area, so, unless the herbivorous inhabitants travel to other lower parts of the reef to feed, it would seem that there must be microscopic plants present, and that they occur in numbers sufficient to make up the basic food supply of the animals. On neighbouring areas, outside the boundaries of the mapped area, certain of the larger rocks extend high enough to have growths of orange-coloured lichen on them. These growths do not, however, appear to be used as food by any of the marine animals.

Also included within the supra-littoral is a small area of sand and shingle with a few boulders (Plate vii). Living in this habitat is a fauna transitional between a marine and a terrestrial community. Here no living plants (visible to the naked eye) are found, but quantities of decaying algae and animals, cast up by the tide, lie about and furnish the bulk of the food supply for the inhabitants. Here also microscopic plants may play a role in the local economy.

B. ANIMALS OF THE SUPRA-LITTORAL.

1. *Animals of the Rocky Substratum.*

Typical inhabitants of the supra-littoral rocks are the periwinkles and barnacles—forms well adapted to withstand the changeable environmental conditions which obtain there. Temperatures show a wide range, since the rocks are exposed to the blazing heat of the summer sun and the cold winds of winter nights and days. Also, on the average, the inhabitants are wet by the sea or splashed by waves only once or twice in the fortnight and, in between these periods of immersion, have to conserve moisture as best they may. Of course, a considerable amount of moisture, in the form of fine spray, is always present in the atmosphere, so the degree of exposure of the animals to desiccation is probably much less severe than one would imagine after casual inspection. Nevertheless, the majority of species from this habitat are specially well adapted to withstand desiccation. They either possess thick, calcareous shells and devices for sealing their tissues off from the atmosphere or else they shelter in cracks and crannies and shady spots where the moisture is retained.

During the hotter parts of the day, when the tide is low, most creatures on the rocks of the supra-littoral remain inactive and withdraw into their shells and hiding places. Only towards dusk, or during the night do they move about and search for food. On grey, moist days, too, considerable activity is manifest and some idea of their normal nightly activities can be gained at such times. The periwinkles move about quite rapidly. The limpets show signs of movement and other inhabitants are also less torpid and hint at the more active phases of their lives. The animals chosen as indicator species for the association from the upper surfaces of rocks are the periwinkle, *Melaraphe unifasciata*, and the barnacle, *Chthamalus antennatus*.

(*a*). *Upper Surfaces of Rocks.*

Two types of periwinkles are commonly found on the higher rocks—the "noddiwink", *Nodilittorina tuberculata*, and the "australwink", *Melaraphe unifasciata*, but since the supra-littoral does not extend to a high level, the fact that *Nodilittorina* can exist on the rocks at a far higher level than *Melaraphe* is not apparent on the area studied. In order to observe this layering of the periwinkles, other parts of Long Reef or other localities have to be visited. On the nearby rocky coast at Harbord (Fig. 1) this layering of the molluscs is very marked and *Nodilittorina* may be found in sheltered cracks at a height of 25–30 feet above zero tide mark. As a rule, the specimens from the highest levels are solitary, large, well-developed adults and the younger specimens are found at the lower extremity of the vertical range, and the individual *Nodilittorina* on the rocks of the western end of Long Reef are smaller specimens, since only the lower level of the supra-littoral area is represented.

Though not attaining to the heights reached by the "noddiwink", the little blue-grey periwinkle, *Melaraphe*, is very conspicuous, being the more numerous of the two. Young ones tend to gather in clusters and huddle together beneath the overhanging edges of small depressions in the rock surface or in cracks and other sheltered spots. Often they are found ringing a small depression, the base of which is covered with crystallized salt. When mature, they too are more solitary in habit and climb to higher levels of the reef.

Both these types of periwinkle, in addition to shutting off their bodies from the air by means of an operculum, seal themselves down to the rock surface by means of a secretion which serves the double purpose of anchoring the shell and retaining the moisture.

A few barnacles occur at scattered intervals on the rocks of the supra-littoral. Often exposed to the full glare of the sun is the species *Chthamalus antennatus*. This barnacle must perforce feed only when the high spring tides cover it. *Chthamalus* occurs only in the lowest part of the supra-littoral. Its shell is low and conical and has closely-fitting valves, lined by a tough, black, membraneous sheath which still further insulates the soft body from evaporation.

A few crabs, *Leptograpsus variegatus*, scuttle over the rock surfaces or shelter in crevices or beneath stones.

*Animals from Upper Surfaces of Rocks in the Supra-littoral at Harbord.**

Name.	*Remarks.*
Melaraphe unifasciata (Gray).	Commonest animal—climbs second highest in the area.
Nodilittorina tuberculata (Menke).	Common—climbs highest of all marine littoral forms—found thirty feet above zero tide level.
Bembicium melanostoma (Gmelin).	Occasional in the lower part of the area—also among *Melaraphe*.
Chthamalus antennatus Darwin.	Scattered on lower parts of the area.
Patelloida submarmorata Pilsbry.	A few in gutters and on surface of rocks in lower region of the area.
Notoacmaea petterdi (Ten.-Woods).	Like the limpet above, occurs scattered on rocks in lower part of the area.
Melanerita melanotragus (E. A. Smith).	Fairly common in pools and sheltered parts of the rocks. Mature specimens.
Leptograpsus variegatus Fabr.	Fairly common—shelters in crevices or pools in the area.

At the lower limit of the supra-littoral a transitional area is found where the inhabitants of the higher community overlap those of the littoral one. Here young, immature specimens of *Melaraphe* and *Nodilittorina* are found in great numbers. Also the heavy "conniwink", *Bembicium melanostoma*, makes an occasional appearance among the *Melaraphe*. Black periwinkles, *Melanerita melanotragus*, are also found as stragglers in crevices of rocks at the high tide limit and for a short distance above it. They show a tendency to congregate in clusters. Once again the transitional community between

* The list of inhabitants of the supra-littoral on the area studied at Long Reef is very similar, except for the absence of the limpets.

supra-littoral and littoral is seen at Harbord more clearly than at Long Reef. There, in addition to the barnacles and periwinkles already mentioned, several types of small limpets are also found, notably *Patelloida submarmorata* and *Notoacmaea petterdi*. A list of the inhabitants from the supra-littoral at Harbord is included rather than the list from the area studied at Long Reef, since the former community is nearer the typical condition found in such areas.

(*b*). *Lower Surfaces of Rocks.*

There is strictly no substratum to furnish this type of habitat on the area studied. There is, however, an area with small boulders in the supra-littoral, but the fauna shows a mingling of marine and terrestrial types and is described below.

One animal, the barnacle, *Tetraclita purpurascens*, would appear to belong to a fauna from beneath rocks rather than to one from the upper surfaces. It is found generally in shaded spots or on the underside of overhanging rocks at Long Reef. At Harbord, it grows on the vertical sides of a gutter in rock, often in shade, and in harbour localities is often found in the supra-littoral on the shaded piers of boat-sheds. It would seem, therefore, to be definitely a photophobe and should on this account be classed as an inhabitant from the lower sides of rocks.

Animals from the Lower (Shady) Surfaces of Rocks in the Supra-littoral.

Tetraclita purpurascens (Wood).	Where it occurs, it is found in dozens, on the vertical sides of gutters and under ledges where there is shade.

2. *Inhabitants of the Sandy Substratum.*

There is no fully-developed animal community on the sandy bottom in the supra-littoral in the area under special observation.

3. *Inhabitants of the Sand and Boulder Substratum.*

(*a*). *An Association where Terrestrial and Marine Forms overlap.*

A peculiar little community, which shows the overlapping of marine and terrestrial faunas, may be found among the small boulders and shingle and in the sand which underlies them. It is situated in the supra-littoral at the western edge of the area studied.

The animal most commonly collected is the amphipod, *Talorchestia novae-hollandiae* Stebbing, which moves about in hundreds when the stones are moved. Attempts to make exact estimates of its numbers, by taking several samples over a set area, failed because of the impossibility of capturing all the specimens owing to their agility in hopping and powers of burrowing in sand. Many earwigs live among the stones, together with the little skink lizard, *Lygosoma leiolepisma guichenoti* (Gray). Ants of the genus *Pheidole*† are numerous, seeking food among the debris of rotting seaweed and other jetsam or carcases of animals caught and held by the stones. The chironomid, *Telmatogeton australicus* Womersley, and a small dipterous insect are to be seen moving about in the debris. Two types of crabs have been captured among the same stones. One of them, the "ghost crab", *Ocypode cordimana* Desm., lives in burrows in the sand. It is not, however, restricted to the small area of stones on sand, but its burrows may be seen all along the high areas of the supra-littoral of the neighbouring sand beach and even in the loose sandy turf of the lower parts of the golf links. The other crab, *Cyclograpsus punctatus* Milne-Edwards, lives under the stones and is not found on the reef outside this restricted area of stones on the sand. Rats and birds‡ are frequently seen to visit this part of the reef when humans are not near.

VI. The Littoral.

As may be seen in Plate vii*a*, the littoral comprises by far the greatest part of the area studied at Long Reef, since it includes all parts between 1 foot 2 inches and 4 feet

† The ant, *Pheidole* sp., was identified by Mr. T. Greaves of the Council for Scientific and Industrial Research, Canberra. The material obtained consisted only of workers minor, so he was unable to make specific identification.

‡ The birds of Long Reef have been dealt with in detail by K. A. Hindwood, *Proc. Roy. Zool. Soc. N.S.W.*, 1941-42 (1942), p. 14.

8 inches above zero tide mark. The littoral, therefore, includes most of the two flat rocky parts, "Grey Shale Point" and "Chocolate Shale Point". A narrow strip inshore of "Stony Bay" is also included, together with the higher parts of the small "islands" lying just off the reef. The types of substratum offered for colonization comprise sandy bottom and rocky bottom.

The slope of the rocks in most of this littoral is gradual, as may be seen in the sections (Text-figure 2). As a consequence, the animal communities, comprising mainly clinging and encrusting types of creatures, are sprawled over wide areas of rock. They do not present the distinctly layered appearance so evident in the animal and plant communities at Harbord, where the rocks slope steeply to the sea. On the rock-platforms, water-filled joint cracks and hollows occur at intervals over most of their areas. As would be expected, these shelter communities normally encountered at much lower levels on the reef.

Only a limited amount of sandy substratum is available in the littoral for colonization. In the upper littoral, a narrow sandy beach lies at the base of the hills, inshore. This strip is then succeeded on the seaward side by a strip of rock-platform which forms the inshore boundary of "Stony Bay". The bottom of "Stony Bay" is a mosaic of sand pockets and small boulders and rocks. Most of the sandy beach inshore (in the littoral) is constantly being shifted about by storms and winds and does not form a suitable habitat either for plants or animals. No visible algae grow there and the few animals encountered are generally roving and scavenging types such as rodents, birds and crabs.

A. Plants of the Littoral.

Most of the plants of the littoral occur on the rocks which offer firm and secure attachment for their holdfasts. In fact, only one type of plant, Eelgrass, *Zostera nana*, was collected from the sandy substratum. It occurs in only one or two very isolated small patches—one in a permanent pool at the south-eastern end of the area studied (Plate viia) and the other near the level of average low spring tides in "Stony Bay" (Plate viia). As a rule, *Zostera* is associated with still estuarine waters, where it is found growing at low tide level, generally in sand with some admixture of silt and mud, so its appearance on the open coast at Long Reef is unusual.

The seaweeds of the rocky reef are an important environmental factor for the animals, providing food and shelter for a great number of inhabitants. For this reason they are dealt with at some length. Considerable seasonal variations were encountered both in the occurrence and the amounts of the various species, but since interest in this case was centred mainly in the fauna, complete checks of the algae were not kept. However, notes of obvious changes were made, and where relevant will be mentioned. In recording the algae, the policy adopted was to record any seaweed in an area, whether it occurred there all the year round or only for a short season. It follows, then, that this description does not necessarily give a complete picture of the algae present at any one time, but rather records the region where an alga would be found on the reef, in its right season.*

Certain algae seem to be present all the year round, though sometimes very immature. Among these are most of the more common species: *Hormosira Banksii*, *Corallina*, *Sargassum* spp., *Phyllospora comosa* and *Ecklonia radiata* var. *exasperata*.

The apparently haphazard arrangement in space of the seaweeds on certain parts of the rocky reef can be satisfactorily explained, only when their distribution is correlated with the levels of the various parts of the reef and the height at which they occur above low water mark.

A map was drawn to show areas exposed at the different stages of the tides. This was done by using the level of the water, on a calm day, and mapping the parts of the reef which were exposed simultaneously at various stages during the rise and fall of the tides. At the same time, observations of the vertical fall of the water level were made, so that the approximate heights of the exposed parts above zero tide level were obtained.

* Original identifications of seaweeds were made by Miss Valerie May, M.Sc., whose task was rendered more difficult by the fact that, in many cases, incomplete specimens were submitted for identification. Subsequent identifications were made by the author.

In the upper part of the littoral, the rocky substratum shows very little growth of permanent, visible algal communities. A few patches of filamentous growth represent the only algae found. They occur only at certain times of the year (March to April) and belong usually to the genera *Ectocarpus* or *Pylaiella*.

In the middle region of the littoral, i.e., the half-tide level and below, the first prominent algal communities appear, and the species are those classified by Oliver (1923) as emergent brown types. The dominant form is *Hormosira Banksii*, which forms, where conditions are favourable, a carpet-like expanse on the upper surface of the flat rock-platforms. Since this algal carpet consists almost entirely of the one species, Hedley (1915) classified it as a Hormosiretum. The best development of a Hormosiretum is seen on "Chocolate Shale Point". In places the *Hormosira* plants are close together as shown in Plate viii, figure 3, but this condition is found only where the *Hormosira* is at least partially submerged, as in a shallow pool. Over the greater part of the rock-platforms it is more widely scattered, as in Plate viii, figure 4.

Occasionally other algae are present in the littoral, *Corallina* being the one most frequently encountered. It is always found in low-lying parts of the reef, where water is retained in rock pools, or in the deeper crevices which develop along the lines of joint cracks in the shale. These algae strictly belong to a lower level of the reef and have migrated upwards where conditions have allowed them to do so. In this account, following the lead of Stephenson (1939), the term "*Lithothamnion*" is used for the encrusting types, and "*Corallina*" for the upright types of the calcareous red algae. "*Amphiroa*" is the only genus treated as distinct. *Scytosiphon lomentaria*, small, stunted plants of *Ulva lactuca*, and small specimens of *Colpomenia sinuosa*, attached to other weeds in pools, also occur in this middle section of the littoral, in their season. In addition to these, there are also several species of green and brown-coloured, filamentous algae such as *Ectocarpus confervoides*, *Pylaiella littoralis* and species probably referable to the genera *Cladophora* and *Enteromorpha*. Most of these filamentous types occur in the small pools or attached to the backs of the animals with calcareous shells which live in the region. Though small, in their season (March–April), they form an important source of food for the molluscs which live here. On "Grey Shale Point" they are particularly plentiful and seem to favour rather muddy situations such as the surface of the argillaceous grey tuffs where a coating of mud (due to weathering) is, as a rule, present. Plate viii, figure 5, shows such a place; the part between the jar and the knife illustrates the general appearance of the rock surface, and several molluscs, coated with the weed, may be seen.

In one or two pools in the inshore part of "Stony Bay", there is a prominent growth of *Ilea fascia* during the months of May, June and July. *Pylaiella* occurs not only in this part of the littoral area, in its season, but also is found wherever bare rocks show below this point.

In the lower part of the littoral—the lower levels of "Island Two" and "Barnacle Point", the southern and eastern ends of "Island One", the top of "T-reef" and a narrow strip round the outer edge of the rock-platform, and in "Stony Bay"—the dominant alga is *Corallina*, which forms a thick carpet-like mass about two inches high on the upper sides of rocks where suitable conditions prevail. A quantity of sand, shells and other debris is imprisoned among the algae and forms a habitat for numerous worms, molluscs, amphipods and insect larvae. The coralline mat is constantly kept moist by the wash of larger waves, at infrequent intervals, except during specially low spring tides or in very calm weather. This moisture requirement appears to be the limiting factor in the environment, since *Corallina* is found all over the reef from high neap tide mark to low tide mark, in any place where there is more or less permanent water, and in consequence, the time of exposure during low tides is not excessive. In some of these pools the temperature may be as much as twelve centigrade degrees warmer than the sea at the outer edge of the reef. Corallines from the upper part of the reef tend, however, to be small and stunted and thick mats of them are not found as on the lower parts.

The *Hormosira* and *Corallina* algal communities are not as distinctly separated from one another, as might be supposed from this account, and in places there is a distinct region of overlap, especially on "Chocolate Shale Point". An example of a community

like this is shown in Plate viii, figure 6, where scattered plants of *Hormosira* may be seen among the corallines. *Hormosira* plants in such a situation never attain the size that they do at higher levels of the reef, probably owing to the increased force of the wave action to which they are subjected.

Other algae occurring in this lower region of the littoral are *Colpomenia sinuosa*, *Dictyota dichotoma*, a few plants of *Sargassum* (very stunted), *Scytosiphon lomentaria* and an alga allied to *Valonia*. Also present is a red alga which occurs as small, bright reddish-green clumps on the outer edge of the reef and forms a habitat for numerous dipterous larvae. This particular alga is, as yet, unidentified but is probably related to *Laurencia*.

Towards the lower part of the littoral, the amount of *Corallina* increases, till at length a community without *Hormosira* is seen; only small algae such as those already mentioned are present and form a "mat". The greater part of "Island One" is covered by such a "mat" and consists mainly of *Corallina* with a number of other small algae forming a mixed algal community. This part is exceedingly favourable to the development of such a community, since most of the larger waves, in breaking, throw quite a considerable quantity of water on to the top of the rocks and, as the latter slope away towards the mainland, the water drains across the island, keeping it in a continually moist condition. The higher, northern edge of the same "island" is comparatively bare of algae and is covered with barnacles and other fixed or clinging animals. In the crevices and pools developed in the weathered joint cracks on "Island One" are a number of algae which belong, as a rule, to a still lower region of the reef. Among these are a large feathery form of *Sargassum*,* *Colpomenia sinuosa* (attached to the *Sargassum*) isolated plants of *Dictyota proliferans*, *Padina pavonia*, *Delesia* sp. and *Zonaria crenata*, while several other species of *Sargassum* are also present. Nowhere else on Long Reef is such a wide variety of species of algae found in such a small area as on "Island One".

As a rule, the *Corallina* occurs as a band a few yards wide at the outer edge of the rock-platforms but, where the reef slopes less precipitously to the sea, the part covered by the *Corallina* may become quite wide.

The distribution of the algae of the permanent pool on "Grey Shale Point" is interesting, since it shows the gradation of algal communities from those of higher to those of the lower parts of the Reef. The shallower, south-western end drains almost completely during low tides, while the northern end remains submerged to a depth of twelve to eighteen inches. As would be expected, the algal communities differ. In the shallow area of the pool (Pl. viii, fig. 7) *Corallina* form a thick carpet among the rocks with *Hormosira*, *Zonaria* and sparse *Sargassum*, while in the deeper part of the pool (Pl. viii, fig. 8) *Corallina*, though present, is less prominent, and *Sargassum*, *Padina pavonia*, *Amphiroa anceps* and *Colpomenia sinuosa* are the dominant forms of algae. Animals characteristic of the seaward parts of the reef also begin to make their appearance in the deeper parts of the same pool.

B. ANIMALS OF THE LITTORAL.

1. *Animals of the Rocky Substratum.*

The animal communities of the rocky bottom are characteristically of the barnacle-mollusc type as defined by Clements and Shelford (1939), with clinging and encrusting types of animals much in evidence.

On the seaward parts of the littoral rocky reef the dominant species are mostly barnacles. Molluscs are more prominent in the higher areas.

Two types of rocky bottom are available in the littoral for colonization—the rock-platform and part of the beach of small boulders in "Stony Bay". Imprisoned among these boulders is a quantity of coarse, gravelly sand, upon which some of the boulders rest.

As would be expected, there is a marked distinction between the animal communities from the two types of rocky bottom. The rock-platform community is of the barnacle-

* In every case the specimens of *Sargassum* were incomplete or too stunted or deformed for specific identification.

mollusc type—the predominant molluscs inshore being of the periwinkle type, while nearer low tide mark the limpet type is prominent. The animal community from the boulder beach in "Stony Bay" resembles the one from the other kind of rocky bottom in type, but includes among its inhabitants many forms more sensitive to desiccation, light, and battering by waves than related species from the rock-platforms. The fauna beneath the boulders, in addition to the barnacle-mollusc association, includes animals which occur also in the sub-littoral fringe, as a comparison of the faunal lists of the two areas will readily show. This is only to be expected because the inhabitants are not subjected to great differences in the amount of exposure to the elements during high and low tides. Many polychaetes and also many of the molluscs are common to both the littoral boulder and sub-littoral fringe areas. There are many hermit crabs inhabiting mollusc shells of all kinds and sizes. Turbellarians and nemerteans are numerous together with polynoids and tube-building polychaetes. Many additional errant polychaetes inhabit the crannies of the rocks and are collected by soaking the latter in formol-sea-water. Chitons are numerous and a wider variety of species is more frequently found in the lower littoral part of the reef than in lower zones. Brittle-stars occur under almost every rock and are also more common in this part than at lower levels, though the actual number of different species is less. The indicator species chosen for this animal association are, therefore, a brittle-star and a chiton. Though neither is a fixed species and both can roam about, they serve this purpose well, since they are limited with regard to their occurrence to this position on the lower surface of rocks. Neither species was observed on the upper surfaces of rocks during night inspections. From this description it is clear that the animal association from the under surfaces of the boulders in the lower part of the littoral of "Stony Bay" is an upward extension of the animal association from the sub-littoral. This is especially true of the inhabitants from beneath boulders resting on the sand. There are, however, boulders which rest on top of others and allow free access for water beneath them. The inhabitants from the lower sides of these rocks correspond to Gislén's hypobiose and include such creatures as chitons, tube-worms, barnacles and other creatures of the barnacle-mollusc type of association. In addition to the animals attached to the surfaces (both upper and lower) of the rocks, there are also a few animals actually burrowing in the stone—corresponding to Petersen's "infauna" and Gislén's "endobiose". Included among the burrowers are many gephyreans (*Phymosoma japonica*), polychaetes and the mollusc, *Cardita excavata*. These have not been listed separately but appear in the list of inhabitants from the under sides of the rocks, since they were generally encountered when collecting in this habitat.

The animal communities from the upper and lower sides of the rocks are described and their inhabitants are listed separately to enable comparisons to be made.

In addition to the above two types of more or less sedentary communities, there are roving types which visit the reef during either high or low tide. At low tide, the chief visitors to the reef are men who do considerable damage to the fauna in their search for fishing bait; seabirds; rats; and insects. At high tide the reef is invaded by many fish and crustaceans searching for food; and also the water brings a large quantity of plankton with it and these form an important source of food for many of the fixed animals. Certain of the roving forms cannot exist away from the sheltered shore since they depend for their food on benthic animals of the littoral area, such animals constituting a kind of "ecotone" between the nekton and benthos.

(a). Upper Surfaces of Rocks.

As already mentioned, owing to the extreme flatness of the rocks, the animal associations have spread out over an unusually wide area and it is very hard to define the limits of any particular one. The policy has been adopted of describing the salient points of the distribution of each of the more important types of animal and then giving a detailed list of all the animals found. By this method it is hoped to convey some idea of the conditions, since any description of the sprawling and fragmentary associations would only be confusing. For convenience of description, the littoral community of the upper sides of rocks has been divided into an upper, middle and lower portion.

A fairly wide sandy beach occupies the upper part of the littoral or tidal zone and in consequence of this the rocky-reef-animal-community is almost entirely missing. There is a slight development of it on "Grey Shale Point", where the conniwink, *Bembicium melanostoma*, and *Melanerita melanotragus* and *Melaraphe unifasciata* are the most prominent types and are of mature size.

Melanerita always avails itself of any position on the upper littoral where water may be expected to be retained and in such favourable spots numbers often huddle together as is shown in Plate ix, figure 9. In crevices or tiny pools the anemone, *Oulactis mucosa*, is frequently found in the upper part of the littoral but, since it covers itself with sand and other debris, it is frequently overlooked (Plate xi, fig. 31). Beneath overhanging rocks, another anemone, *Paractis papaver*, sometimes occurs in the inshore part of the rock-platform. *Paractis* is most plentiful, however, on lower parts of the reef and occurs in dozens among the patches of *Hormosira* on "Chocolate Shale Point" and in the area adjacent to the *Hormosira*, on the seaward side.

Crustacea abound in the littoral, especially barnacles which, in places, cover the rocks to the exclusion of other animals. The barnacle which climbs to the upper parts of the littoral is *Chthamalus antennatus*, while under the overhanging sides of rocks *Tetraclita purpurascens* is found at almost the same level. Seawards of these, in the middle littoral, are many, tiny, closely-packed individuals of *Chamaesipho columna*. It is the dominant barnacle over a great width of the flat rock-platforms and on the tops of the larger boulders in "Stony Bay" (Pl. ix, fig. 10). Below *Chamaesipho* again, in the lower littoral, the dominant barnacle is *Tetraclita rosea*, which covers the rocks on the top of "Barnacle Point" and a narrow strip all round the outer edge of the rock-platform. It is plentiful, and a close view of the top of "Barnacle Point" gives an idea of the numbers occurring there (Pl. ix, fig. 11). This illustration shows two types of barnacle: the larger one is *Catophragmus polymerus*, commonly called the surf barnacle. The smaller and more numerous one is *Tetraclita rosea*. Only about twenty specimens of *Catophragmus* were to be found on the part of the reef studied, but a better developed community may be seen at Harbord. On the lowest part of the littoral the giant barnacle, *Balanus nigrescens*, occurs at scattered intervals on the rocks (Pl. ix, fig. 12). In more sheltered parts of the reef, such as in "Stony Bay" and between "Island One" and the mainland, a purple barnacle, *Balanus imperator*, occurs, generally at a slightly lower level than *B. nigrescens*. *Balanus imperator* is encountered only occasionally on the upper sides of rocks.

Among the limpets found on the littoral at Long Reef, *Cellana tramoserica* is the highest climber, and its range extends from the high neap tide limit down to the lower limit of the littoral (Pl. ix, fig. 10). Below this the limpet, *Patelloidea alticostata antelia* is found, and below this again is *Patelloidea alticostata complanata*, a species which is almost invariably coated with *Lithothamnion* and is strictly an inhabitant of the sub-littoral fringe of the reef.

Among other gasteropods in the littoral, *Bembicium* and *Melanerita* occur on the higher levels. Below these, two small species of *Melaraphe* are found, along with the two species of the zebra-striped *Austrocochlea* which extend over a wide area of reef, especially among the algae (Pl. ix, fig. 13). In the lower parts of the littoral three types of turban shells live among the seaweeds, namely, *Ninella torquata* (Pl. viii, fig. 3), *Lunella anguis* and *Turbo militaris*. The mulberry shell, *Morula marginalba* and small *Melanerita* are always found in sheltered spots or in small pools in the middle part of the littoral.

The gasteropods from the lowest parts of the tidal area are all large, heavy forms such as the whelks, *Cymatilesta spengleri* and *Charonia rubicunda*, and the "cart-rut" shell, *Dicathais orbita*. They all frequent pools in crevices or other areas, sheltered from the force of the waves.

Among the chitons, there is a definite order in which the species appear from the higher parts of the reef down to the low water mark.

Highest of all in the littoral is *Sypharochiton septentriones*, which extends down to the level of the low neap tide mark (Pl. xi, fig. 35). Below this the striped-girdled *Onithochiton quercinus* is found in small depressions in the rock surface, in parts also

occupied by the large barnacle, *Balanus nigrescens*. The small hollows occupied by these latter chitons fit so exactly the shape of their inmates, that it would appear reasonable to suppose that the hollows have been made in the rock by a secretion from the animal or by the workings of the foot. A series of these hollows is shown in Plate ix, figure 12, and the chitons may be seen occupying the holes filled with water. A third chiton occurring in the littoral on the upper sides of stones, chiefly in pools, is the large *Poneroplax pacteliana*, with its "hairy" girdle. Sheltering among the stones in the *Hormosira* patches, a few small specimens of *Ischnoradsia australis australis* are found together with *Haploplax lentiginosa* and *Haploplax smaragdina*.

Where there is plenty of seaweed for food, the gasteropods are particularly numerous. Plate ix, figure 13, shows an area in the *Hormosira* where the *Austrocochlea* and *Cellana* are gathered in a cluster during the low tide. Some idea of the abundance of these shells may be gained by counting the number contained in this small space of a few square feet. On slightly raised parts, in the middle of the littoral, some parts of the rock are almost completely covered by the tiny barnacle, *Chamaesipho columna*, as is shown in Plate ix, figure 10, where this species and the limpet, *Cellana*, are the only two to be seen over a square foot or more of the surface. Crabs run all over the littoral part of the reef during the low tides, and they follow the water as it rises and falls, or take shelter under stones. The red, black-nippered crab, *Ozius truncatus*, and the common "steel-back" crab, *Leptograpsus variegatus* and *Pachygrapsus transversus* are found all over the reef. Another red, "short-furred crab", *Plagusia capensis*, is found on the lower parts of the area.

On the wide flat part of the littoral, scattered tubes of the serpulid, *Galeolaria caespitosa*, are seen but they do not form a complete covering for the rocks (Pl. ix, fig. 15). But in the lowest part of the littoral, in places where there are vertical walls of rock or rounded boulders, this same species of *Galeolaria* completely encrusts the rock surface and among the tubes is a large sheltering fauna of worms, bivalves, tiny gasteropods, gephyreans and tube-building polychaetes. Plate ix, figure 16, shows such a community in "Stony Bay". The list of animals from the worm-tube community is as follows:—Mollusca: *Lasaea australis* and *Trichomya hirsuta* are the commonest forms and there is also a number of small gasteropods and the chiton, *Acanthochiton granostriatus*. Crustacea: Amphipods in great numbers and the peculiar cirripede, *Ibla quadrivalvis*. Vermes: Many eunicid worms and also the tube-builders, *Idanthyrsus pennatus* and *Salmacina australis*, and nemerteans live in the spaces between the *Galeolaria* tubes.

On the outer part of the reef, where the surf breaks at all times, the ascidian, *Pyura praeputialis*, makes its appearance. At first, a few stragglers occur at widely separated intervals (Pl. ix, fig. 17) and then, where conditions become more favourable, they may be seen in the closely packed clumps (Pl. ix, fig. 18), which offer shelter to a community of worms, chitons (*Meturoplax retrojecta*), bivalves and amphipods.

A few echinoderms are found on the littoral, mostly in preformed holes which are filled with water. They are thus obviously stragglers from a lower sub-littoral community or members of the community which lies hidden under stones where water circulates freely (Gislén's hypobiose). The commonest sea-star is *Patiriella exigua* (Pl. xi, fig. 31), which lives anywhere on the area where water lies, and it is often found with the anemone, *Oulactis mucosa*. On lower levels of the reef, *Patiriella calcar* (Pl. xi, fig. 34) and *P. gunnii* are found in rock pools, as is also the sea-urchin, *Heliocidaris erythrogramma*.

Amphipods are exceedingly numerous and may be found in weeds, in pools, and among the clumps of worm tubes or ascidians. The list of species is given below.

One special association deserves mention. It is found in the mat of seaweeds at the level of the low tides among the *Corallina*, etc. All the members of the community are small and, with the exception of the kelp fly, *Clunio pacificus*, live in the sand and debris imprisoned by the algae. There, hundreds of nereid and eunicid worms live together with amphipods and the tiny bivalve, *Lasaea australis*. The fissurellid, *Montfortula conoidea*, is common, and larvae of several types of Chironomidae abound. A small nematode (Family Enoplidae) also occurs and, in the season, scores of the

sea-hare, *Tethys norfolkensis*, browse on the crisp green algae. Numbers of tiny gasteropods also abound, and are listed in the addendum to the sub-littoral fringe faunal list.

Many fish and Crustacea must visit the littoral during high tides, since a large variety has already been recorded, and in their season, nudibranchs, sea-hares and a number of other forms come to deposit their eggs.

Several pulmonates or near-pulmonates occur in the littoral. These false limpets are all members of the genus *Siphonaria*. *S. virgulata* occurs highest on the rocks and below its range, *S. baconi* is found in high rock pools and is frequently obscured by a growth of filamentous algae. *S. scabra* inhabits a wide area of reef, occurring with *Cellana tramoserica* and being especially plentiful on "Grey Shale Point". Several *Siphonaria scabra* are seen in the right-hand lower corner of Plate x, figure 19.

The following is a complete list of the more common species from the upper surfaces of rocks in the littoral area:

Animals from Upper Surfaces of Rocks in the Littoral.

1. UPPER PART OF THE LITTORAL.*

CRUSTACEA:

Chthamalus antennatus Darwin, **Tetraclita purpurascens* (Wood). Amphipoda: not yet identified. *Leptograpsus variegatus* Fabricius, **Ozius truncatus* M. Edw.

MOLLUSCA:

Lamellibranchiata: *Saxostrea commercialis* (Iredale and Roughley). Gasteropoda: *Austrocochlea concamerata* (Wood), *Austrocochlea obtusa* (Dillwyn), *Bembicium melanostoma* (Gmelin), *Melanerita melanotragus* (E. A. Smith), *Bedeva hanleyi* (Angas).

2. MIDDLE PART OF THE LITTORAL.

COELENTERATA:

Oulactis mucosa Drayton, *Paractis papaver* Drayton.

POLYCHAETA:

Galeolaria caespitosa Hasw., *Syllis variegata* Grube, *Nereis pelagica* Linn. var.

BRYOZOA:

**Membranipora membranacea* Linn.

CRUSTACEA:

Chamaesipho columna Spengler, *Tetraclita rosea* Darwin, **Ozius truncatus* M. Edw., *Leptograpsus variegatus* Fabr., **Plagusia capensis* de Haan, **Pachygrapsus transversus* Gibbes. *Amphipoda (various).

ECHINODERMATA:

**Heliocidaris erythrogramma* (Valenc.) in rock pools, **Patiriella calcar* (Lamk.), **Patiriella exigua* (Lamk.).

MOLLUSCA:

Lamellibranchiata: **Trichomya hirsuta* (Lamk.). Amphineura: *Sypharochiton septentriones* (Ashby), *Haploplax lentiginosa* (Sowerby), *Haploplax smaragdina* (Angas). Gasteropoda: *Austrocochlea* (olim *Monodonta*) *concamerata* (Wood), *Austrocochlea obtusa* (Dillwyn), *Cellana tramoserica* (Dillwyn), *Siphonaria baconi* Reeve, *Siphonaria scabra* Reeve, *Morula marginalba* (Blainville), *Bembicium melanostoma* (Gmelin), *Agnewia tritoniformis* (Blainv.), *Montfortula conoidea* (Reeve), *Melaraphe unifasciata* (Gray), *Melaraphe infans* (E. A. Smith), *Melaraphe acutispira* (E. A. Smith), **Flabellina ornata* (Angas).

3. LOWER PART OF THE LITTORAL.

PORIFERA:

Chalina sp.; other sponges not identified.

COELENTERATA:

Oulactis mucosa Drayton, *Cereus tuberculosus* Quoy & Gaim., *Paractis papaver* Drayton.

POLYCHAETA:

Galeolaria caespitosa Haswell, *Syllis variegata* Grube, **Spirographis australiensis* Haswell, **Syllis closterobranchia* Schmarda, **Eusyllis*, near *kerguelensis* of McIntosh, **Nereis pelagica* Linn., local var., **Perinereis novae-hollandiae* Kinberg, *Pseudonereis anomala* Gravier, *Lysidice collaris* Grube, **Idanthyrsus pennatus* (Peters) and other polychaetes as yet unidentified.

GEPHYREA:

Phymosoma japonica Grube, in crevices.

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* The asterisk denotes that the animal is found also under stones and that it is not confined to the upper parts of the rocks on the reef.

Bryozoa :

**Membranipora membranacea* Lamk.

Crustacea :

Balanus nigrescens Lamk., *Tetraclita rosea* Darwin, *Calophragmus polymerus* Darwin, **Ozius truncatus* M. Edw., **Pachygrapsus transversus* Gibbes, *Tumulosternum longimana* (Haswell), **Plagusia capensis* de Haan, **Plagusia glabra* Dana, *Naxia tumida* Dana. Amphipoda as follows: *Elasmopus crassimanus* (Miers), *Elasmopus diemenensis* Hasw., *Elasmopus subcarinatus* Hasw., *Paramoera megalophthalma* (Hasw.), *Hyale nigra* (Hasw.), *Ampithoe cinerea* Hasw., *Moera hamigera* (Hasw.), *Moera mastersi* (Hasw.), *Ceradocus rubromaculatus* (Stimpson), *Exoediceros* sp., *Pontharpenia villosa* (Hasw.), *Eusiroides monoculoides* (Hasw.), *Podocerus cristatus* (Thompson), *Podocerus labatus* Hasw., *Grubia setosa* (Hasw.), *Eurytheus dentifera* Hasw.

Insecta :

Chunio pacificus Edw., Chironomid larvae (*Tanytarsus* type).

Echinodermata :

**Patiriella exigua* (Lamk.), **Patiriella calcar* (Lamk.), **Patiriella gunnii* (Gray), **Coscinasterias calamaria* (Gray), **Heliocidaris erythrogramma* (Valenc.).

Mollusca :

Lamellibranchiata : **Lasaea australis* (Lamarck), *Pinctada perviridis* (Reeve), **Trichomya hirsuta* (Lamarck). Amphineura : *Acanthochiton kimberi* (Torr), **Metaroplax retrojecta* (Pilsbry), **Haploplax smaragdina* (Angas), *Onithochiton quercinus* (Gould), *Poneroplax paeteliana* (Thiele), **Ischnoradsia australis australis* (Sowerby), **Ischnochiton elongatus crispus* (Reeve). Gasteropoda : *Siphonaria scabra* Reeve, *Ninella torquata* (Gmelin) (olim *Turbo stamineus*), *Lunella anguis* (Gmelin) (olim *T. undulatus*), *Turbo militaris* (Reeve), *Bellastraea sirius* (Gould), *Dicathais orbita* (Gmelin), *Bembicium melanostoma* (Gmelin), small, *Cymatilesta spengleri* (Perry), *Montfortula conoidea* (Reeve), *Charonia rubicunda* (Perry), *Agnewia tritoniformis* (Blainville), **Maculotriton australis* (Pease), **Flabellina ornata* (Angas), **Dendrodoris pantherina* Angas, *Tethys angasi* (Sowerby), *Tethys norfolkensis* (Sowerby).

Ascidiacea :

Pyura (olim *Cynthia*) *praeputialis* (Stimpson) ; compound ascidians (unidentified).

(*b*). *Lower Surfaces of Rocks and in Rocks.*

A general description has already been given of the animals from this habitat. The boulder area available for colonization lies in "Stony Bay" in the part which corresponds to the lower levels of the littoral rock-platform. There is an intermingling of a barnacle-mollusc type of association and a sub-littoral fauna, and the lower sides of rocks frequently have barnacles like *Tetraclita radiata* and *T. purpurascens* attached to them, and chitons of many species are very numerous. Wanderers from the sub-littoral are represented by polychaetes and brittle-stars and other echinoderms. Like the inhabitants of the rock-platform substratum, the members of this fauna are predominantly phytophagous and plankton feeders with some predatory forms. Two fairly large and easily identified species—a brittle-star, *Ophionereis schayeri*, and the chiton, *Ischnochiton versicolor versicolor*—have been chosen as the indicator types for this association, of which a brief account is now given.

(i). Ophionereis–Ischnochiton versicolor *Association*.—This association has as its most prominent, large forms, several species of brittle-stars of which *Ophionereis schayeri* is the commonest and has, therefore, been chosen for an indicator species. The other indicator chosen is *Ischnochiton versicolor versicolor*, as this form reaches its best development here. Other common species are the hermit crab, *Eupagurus lacertosus* var. *nana* (a small form inhabiting many different kinds of small mollusc shells) and several species of tube-worm. *Salmacina*, the fine tube-worm, does not, however, occur in prominent growths, as it does lower down on the reef.

Plate x, figure 20, shows the lower side of a stone from this association. On it, hundreds of the tiny tubes of *Spirorbis* may be see and the tubes of several other worm types as well. Two specimens of the "apricot pleurobranch", *Pleurobranchus punctatus*, are seen together with two types of mollusc eggs. The large worm-tube is *Vermilia rosea*, which occurs typically in a solitary manner, as is seen in the photograph. A small compound ascidian is also found frequently in the association but has not been identified.

A number of molluscs cling beneath the rocks and they are listed below. Most prominent among them are the chitons, both with regard to size and number. The

following list contains the common species from the lower surfaces of boulders in the littoral.

*Animals from the Lower Surfaces of Rocks and in Rocks in the Littoral.**

COELENTERATA :

**Clavularia rosea* Studer. Turbellaria : **Trippylocelis typica* Haswell, **Leptoplana australis* Laidlaw.

NEMERTINEA :

Black nemertean with white bands. Green nemertean. Purplish-black nemertean.

POLYCHAETA :

**Eurythoe complanata* (Pallas), **Eunice siciliensis* Grube, **Eunice antennata* (Savigny), **Syllis closterobranchia* Schmarda, **Syllis variegata* Grube, **Thormora argus* Val., **Lepidonotus melanogrammus* Hasw., **Lepidonotus bowerbankii* Baird, **Harmothoe* sp., **Spirorbis* sp., **Vermilia rosea* Hasw., *Galeolaria caespitosa* Hasw.

GEPHYREA :

Phymosoma japonica Grube (buried in the substance of the rock).

BRYOZOA :

**Smittia trispinosa* (Johnston), **Schizoporella biturrita* Beuss, **Membranipora membranacea* Linn., **Catenaria* sp., **Scrupocellaria* sp., **Menipea* sp., **Craspedozoum roberatum* Hincks, **Microporella* sp., **Crepidacantha poissonii* Aud. or Savigny, **Lepralia* sp., **Retepora* sp., **Idmonea* sp.

CRUSTACEA :

Tetraclita purpurascens (Wood), *Ibla quadrivalvis* Cuvier, **Betaeus* sp. 1 (undescribed), **Betaeus* sp. 2, **Betaeus australis* Stimp., *Betaeus trispinosa* Stimp., **Paraxanthias elegans* Stimp. (olim *X. atromanus* (Hasw.)), **Pilumnis rufopunctatus* Stimpson, **Ozius truncatus* M. Edw., **Pachygrapsus transversus* Gibbes, *Eupagurus sinuatus* Stimp., **Eupagurus lacertosus* var. *nana* Henderson, **Virbius australiensis* Stimp., **Crangon strenuus* (Dana), **Crangon novae-zealandiae* (Miers). *Amphipods (see list on page 239).

MOLLUSCA :

Lamellibranchiata : **Chama fibula* Reeve, **Pinctada perviridis* Schumacher, **Lasaea australis* Lamk., **Anomia walteri* Hector, **Kellya solida* Angas, *Trichomya hirsuta* (Lamk.), *Cardita excavata* Deshayes (boring into rock), *Austrolima nimbifer* Ired., *Limatula strangei* (Sowerby), *Lactemiles strangei* Deshayes. Gasteropoda : *Stomatella imbricata* Lamk., *Clanculus omalomphalus* Adams, *Gena strigosa* Adams, **Cacozeliana lacertina* (Gould), **Pseudomycla dermestoidea* (Lamk.), **Pleurobranchus punctatus* Q. & G., **Eurytrochus strangei* (A. Adams), *Ravitrona caputserpentis* (Linn.), *Terebra* sp., *Baryspira dyspetes* (Ired.), *Pyrene* sp. (too immature for identification), **Rissolina angasi* Pease, *Crosseola concinna* (Angas), *Anafossarus sydneyensis* Hedley, *Floraconus aplustre* Reeve, *Floraconus papilliferus* (Sowerby), *Onchidium damelii* Semper. Amphineura : **Cryptoplax mystica* Iredale & Hull, *Haploplax smaragdina* (Angas), *Haploplax lentiginosa* (Sowerby), **Acanthochiton granostriatus* Pilsbry (among worm tubes), **Acanthochiton pilsbryi* Sykes, **Callistelasma antigua* Reeve, **Ischnochiton elongatus crispus* (Reeve), **Ischnochiton versicolor versicolor* (Sowerby), **Ischnoradsia australis australis* (Sowerby), young. Cephalopoda : **Octopus cyaneus* Gray, **Octopus maculosus* Hoyle.

ECHINODERMATA :

Asteroidea : **Patiriella calcar* (Lamk.), **Patiriella exigua* (Lamk.), **Patiriella gunnii* (Gray), **Coscinasterias calamaria* (Gray), **Asterina inopinata* Livingstone, **Allostichaster polyplax* (M. & T.). Ophiuroidea : **Ophiactis resiliens* Lyman, **Ophiarachnella ramsayi* (Bell), **Ophionereis schayeri* (M. & T.), **Placophiothrix spongicola* (Stimp.). Echinoidea : **Heliocidaris erythrogramma* (Valenc.).

ASCIDIACEA :

Small compound ascidian as yet unidentified.

PISCES :

Volgiolus costatus (Ogilby), *Limnichthys fasciatus* Waite, *Lepidoblennius haplodactylus* Steindachner.

The three foregoing species are often found clinging to the lower surfaces of rocks turned over for inspection.

2. *Animals of the Gravelly-sand Substratum.*

Only a very limited area of sand occurs in the littoral (Plate viia). In fact, so limited is its extent that only small patches of eel-grass or *Zostera* are established in it (Pl. x, fig. 21); they are too small to support the numerous animals usually associated

* Animals marked with an asterisk occur also in the Sub-littoral Fringe Association, beneath boulders.

with this type of growth. A few molluscs live among, and feed on, the *Zostera*. They comprise three species belonging to two genera: *Austrocochlea concamerata*, *A. obtusa* and *Bembicium melanostoma*. Scattered specimens of the tube-worm, *Spirorbis*, are attached to the leaves of the eel-grass. In the sand itself only an occasional polychaete is encountered. There was in no sense a well-developed bivalve-worm association similar to the one in the sub-littoral of the sandy bottom.

3. *Roving Animals.*

In examining the fauna of the rocky reef, it was found that there was a small collection of roving forms which sheltered during the low tide periods, but which came out at high tide to forage over the rocks. These take shelter in the rock pools on the flat reef or hide among the stones in "Stony Bay". The list includes some fish, prawns, and hermit crabs. Most of them are found on the lower levels of the reef, i.e., from the low neap tide mark down to the lowest level reached by the receding tide, and beyond. Men, rats and birds visit the reef during low tides. The list of roving fish and Crustacea is as follows:

PISCES:

Limnichthys fasciatus Waite, *Lepidoblennius haplodactylus* Steindachner, *Vauclusella annulata* (Ramsay & Ogilby), *Pictiblennius iredalei* Whitley, *Verdithorax prasinus* (Richardson).

CRUSTACEA:

Hippolyte australiensis (Stimpson), *Alope australis* (Baker), *Leander serenus* Heller, *Leander intermedius* Stimpson, *Eupagurus sinuatus* Stimpson, *Eupagurus lacertosus* var. *nana* Henderson, *Cancellus typus* M. Edw.

VII. THE SUB-LITTORAL FRINGE.

All parts of the reef, which lie lower than 1 foot 2 inches above zero tide mark, belong to the sub-littoral, and of this the upper part is the sub-littoral fringe—the strip laid bare when low spring tides occur. The sub-littoral fringe at Long Reef thus comprises a comparatively narrow strip right round the outer edges of the rock-platforms as well as a fairly wide area in "Stony Bay" (Plate viia). No definite level can be fixed as denoting the lower margin of the sub-littoral fringe, since it varies so greatly with the changes in wind and other weather conditions. The tide frequently falls to a level of 6 or 7 inches below the zero mark, but when a very low tide (−7 inches) coincides with a strong off-shore wind, the tide recedes even further, and leaves practically the whole of "Stony Bay" above water level or covered by only a few inches of water.

A wide strip along the western edge of the area studied (Pl. x, fig. 23), the whole of "T-Reef" (Pl. ix, fig. 14) and the boulders which lie between the latter and the main platform, belong to the sub-littoral fringe. In addition to these parts, the boulders between "Island One" and the main reef are uncovered by low spring tides; also quite a wide, gently sloping part of the platform of "Grey Shale Point", in the region of "Little Bay" (Pl. xi, fig. 30).

By far the greater part of the sub-littoral fringe consists of rock substratum, part of which is made up of fairly large boulders (Pl. viii, fig. 2) and part again by the outer edge of the shale rock-platforms. Between the boulders in "Stony Bay" are numerous small pockets of gravelly-sand which constitute the only other type of bottom offered for colonization in the sub-littoral fringe. In it is developed an animal community of the bivalve-worm type. The rocky substratum has typical rock-dwelling communities on both the upper and lower surfaces. The upper sides of the rocks provide anchorage for many types of algae, of which the predominant form is *Sargassum*. The "dwarf kelp", *Ecklonia*, and the "bubble weed", *Phyllospora*, are also first encountered in the sub-littoral fringe, where they are attached to the tops of boulders in "Stony Bay" and around the outer edges of the reef. The sand-bottom, on the other hand, supports no large algae, but, owing to the mosaic-like arrangement of the sand and boulders in "Stony Bay", the seaweeds growing on the rocks are in close proximity to the sand-bottom community.

A. ALGAE OF THE SUB-LITTORAL FRINGE.

Where the reef slopes more gradually to the sea, the sub-littoral fringe is wider and it is best developed on the western edge of the reef (Pl. x, fig. 23). In this illustration,

the *Sargassum* community occupying this region of the shore is seen as a dark area on the edge of the rocky reef nearest to the camera.

On the rock-platforms, and in "Stony Bay" where boulders offer surfaces of attachment, the dominant alga in the sub-littoral is a *Sargassum* as yet not specifically determined. Other forms found are corallines (*Lithothamnion* and *Corallina* types), and further species of *Sargassum* as well as several of the smaller kinds of algae already mentioned as occurring in the pools on "Island One". Plate x, figure 22, illustrates an area of the rock-platform exposed during a specially low tide and the nature of the seaweed community is well shown.

Plate x, figure 24, shows the appearance of "Stony Bay" during an average low spring tide. The algae on the rocks comprise for the most part *Sargassum*, with some corallines present, though the latter are not as prevalent as they are on the rocky platforms. Other algae from the area are *Zonaria crenata* and *Colpomenia sinuosa*. There are at least two distinct species of *Sargassum* in the "Bay", one small and tufty and the other long and plumose. The small tufty form is the one common on the rock-platforms which it carpets. When exceptionally low tides occur (once or twice in a year) it is possible to investigate a still lower part of the sub-littoral in "Stony Bay". Algae from this lower part include the encrusting coralline, *Lithothamnion*, *Gymnosorus variegatus*, *Dictyota dichotoma*, *Delesia* sp., and the other coralline, *Amphiroa anceps*. To this list should be added several species of the Rhodophyceae, but they have as yet not been identified. Below this area is a most distinct community where the large *Phyllospora comosa* is the dominant type of alga. It is found attached to the upper surfaces of the boulders which lie around the outer edge of the reef, in the deeper water. During average low spring tides *Phyllospora* lies on the surface of the water as seen in Plate x, figure 25. Occasionally, when very low tides occur, *Phyllospora* from a lower level of the reef is exposed above the water level (Pl. xi, fig. 36). Associated with it, and in far greater quantities, are several types of corallines which occur as a kind of undergrowth. *Amphiroa anceps* is the chief of these, while those parts of the rock not covered by the holdfasts of the other weeds, or by the attachments of animals, are covered by the encrusting form, *Lithothamnion*. Other algae in the same community are *Dictyota proliferans*, *Blossevillea spartoides*, the feathery form of *Sargassum*, *Delesia* sp., and a small fan-like form, *Gymnosorus nigrescens*.

Even during the lowest spring tides, only the upper part of the *Phyllospora* community is exposed. In the area where it is permanently submerged a few sporadic plants of *Ecklonia radiata* var. *exasperata* appear but, out to sea, the amount of *Ecklonia* increases and it, in turn, becomes the dominant large alga. The *Ecklonia* community forms the local equivalent of the laminarian zone found in the sub-littoral region in higher latitudes. Associated with the *Ecklonia* are *Amphiroa anceps*, *Lithothamnion*, *Corallina*, *Sargassum tristichum*, *Cladosleptus verticellatus* and a number of species of the Rhodophyceae. This list is by no means complete, since it has been compiled from the results of collecting the seaweeds cast up on the beach after heavy storms, such weeds being attached to the holdfasts of the *Ecklonia*. The reason for including this small and sketchy list is that so little is recorded of the flora or fauna of the sub-littoral region of the local seashore.

B. ANIMALS OF THE SUB-LITTORAL FRINGE.

1. *Animals of the Rocky Substratum.*

The animal association from the rocky substratum is typically of the barnacle-mollusc type. The barnacles, however, do not cover the bottom to the exclusion of other forms, as they do in the littoral region. On the other hand, gasteropods are very numerous. "Cart-rut" shells (*Dicathais orbita*) and "tent" shells (*Bellastraea sirius*), and numerous limpet-like forms are found on the upper sides of the rock-platforms, while "elephant snails" (*Scutus antipodes*), nudibranchs, pleurobranchs, sea-hares and numerous other gasteropods live on the lower sides of boulders or in dark rock pools or preformed holes on the main rock-platform. Since, however, in the sub-littoral fringe the most conspicuous forms appear to be sea-urchins and chitons, they have been used as indicator species to denote the associations. Other animals encountered are worms, prawns and great numbers of amphipods.

As in the case of the littoral, a few animals have been found boring into the interstices and the solid substance of the rock. These are listed with the surface-living forms but a note is appended to denote the fact that they live actually in the rock. They are the same group of animals which occurred in similar positions in the littoral.

(a). Upper Surfaces of Rocks.

Chitons and echinoderms have become the dominant large animals among the inhabitants of the upper sides of rocks in the sub-littoral fringe. There is also a considerable number of gasteropods found, as well as many prawns, amphipods and barnacles. Despite the fact that the barnacle, *Balanus nigrescens*, is a conspicuous form, the indicator species chosen to denote this association are the sea-urchin, *Heliocidaris erythrogramma*, and the chiton, *Onithochiton quercinus*.

(i). Heliocidaris–Onithochiton *Association*.—The inhabitants of this community differ considerably from those on the higher levels of the reef. Barnacles and gasteropod molluscs are no longer the dominant organisms, though they may still be found on the rocks. Sea-urchins, chiefly *Heliocidaris erythrogramma*, and chitons are the conspicuous large types and occur in every water-filled crevice or rock pool. Holes are excavated in the rocks by both these animals and, while rock boring has long been associated with the sea-urchin, *Heliocidaris*, it has not been recorded locally for the particular chiton, *Onithochiton quercinus* (see Pl. ix, fig. 12).

Plate xi, figure 30, gives a close view of the rock surface in the sub-littoral fringe during an especially low tide (approximately –10 inches). Each of the dark cavities contains three or four specimens of *Heliocidaris* and often a number of *Onithochiton*.

The prawns, *Rhynchocinetes rugulosus*, *Hippolyte australiensis* and *Alope australis*, are commonly found on the *Sargassum*. In lower parts of the sub-littoral fringe, where little light penetrates, a few isolated specimens of the barnacle, *Tetraclita radiata*, are found, while in places exposed to light, but not to the severe action of the waves, another barnacle, *Balanus imperator*, is quite a prominent inhabitant. The conspicuously large barnacle, *Balanus nigrescens*, lives on the more exposed parts of the sub-littoral fringe.

A number of different sponges encrust the rocks. At least seven species may be recognized, but of these only three have been identified. They are *Gellius raphiophora*, *Leucandra saccharata* and *Chalina palmata*. Others are *Chalina* sp. (Pl. x, fig. 26), *Luffania* sp. (commensal with the bivalve, *Reniella spongiarum*), and *Latrunculia* sp.

Many errant polychaetes are obtained by soaking the algae or rocks in very weak solutions of formol-sea-water. Tubiculous polychaetes are also present, and are found in sheltered spots—generally in the nooks and crannies in the vertical walls of the rock-platform. *Spirographis australiensis* and *Idanthyrsus pennatus* are two common tube-worms in this part, occurring in rock pools or preformed holes. They thus truly belong more to the habitat of the lower side of rocks.

The names of the amphipods which occur in thousands in the algae are listed below. Other crustaceans present are the weed-crabs, *Naxia tumida* and *Menaetheus monoceros*, both of which camouflage their bodies with pieces of seaweed attached to and growing on the carapace.

Kelp flies, *Clunio pacificus*, are common during the low tide period and, as far as can be observed, they remain clinging to the weeds while the waves break over them, emerging unwet and undamaged, even after submergence in a considerable wash.

When lumps of rock are broken off and immersed, as previously mentioned, in formol-sea-water solution, many polychaetes, gephyreans and crabs are obtained, driven out of their hiding places by the poison. Species obtained in this manner include the gephyrean, *Phymosoma japonica*; crabs, *Eriphia norfolcensis*, *Actaea tomentosa*; and molluscs, *Arca fasciata*, *Venerupis crenata*, *Ravitrona caputserpentis* and *Floraconus papilliferus*.

Hundreds of gasteropods live in the algae of the sub-littoral fringe, and the great majority are exceedingly minute. Large, prominent forms are the "cart-rut" shell, *Dicathais orbita*, and the "tent" shell, *Bellastraea sirius*. Limpet-shaped gasteropods are numerous, since this shape is best adapted for withstanding the action of the surf.

Limpet species include *Patelloida alticostata complanata*, *Patellanax squamiferus*, *Patella perplexa*, *Radiacmaea insignis* and the tiny cap-limpet, *Sabia foliacea*. Limpet-shaped fissurellids include *Tugali parmophoidea*, *Montfortula conoidea*, *Sophismalepas nigrita* and the "keyhole limpet", *Eligidion audax*.

Other gasteropods are visitors at certain times of the year. These are the nudibranch, *Casella atromarginata*, the "bubble shell", *Hydatina physis*, and sea-hares, *Dolabrifera brazieri* and *Tethys angasi*. Many kelp shells live on the thalli of the algae. Species represented are *Phasianotrochus eximius*, *Astelena scitula*, *Phasianella virgo* and the "pheasant shell", *Mimelenchus ventricosus*.

The best development of the sub-littoral fringe association is found on "T-Reef", the nature of which may be seen in Plate ix, figure 14, and in the area between "Island One" and the main reef. In the spaces between the rocks on "T-Reef", occasional specimens of the long-spined sea-urchin, *Centrostephanus rodgersii*, may be collected along with the comparatively rare *Heliocidaris tuberculata*. *Centrostephanus* is more commonly seen on the bottom in the deeper water round the outer edge of the reef.

The following list contains the species which are most common in the sub-littoral fringe on the upper sides of rocks.

*Animals from Upper Surfaces of Rocks in the Sub-littoral Fringe.**

PORIFERA:

**Chalina palmata* (Lamk.), **Chalina* sp. (purple sponge), *Latrunculia* sp., **Gellius raphiophora* var., *Leucandra saccharata* Baeck., *Luffania* sp.

COELENTERATA:

Cereus tuberculosus Quoy & Gaim., *Myriothela australis* Briggs (on *Ecklonia*).

NEMERTINEA:

*Green nemertean.

POLYCHAETA:

**Nereis pelagica* Linn., local var., **Perinereis novae-hollandiae* Kinb., *Eunice antennata* (Savigny), **Idanthyrsus pennatus* (Peters), *Spirographis australiensis* Hasw. Soaked from ascidian clumps: *Nereis zonata* Malmgren var. *pessica* Fauvel., *Pseudonereis masalacensis* Fauvel., *Perinereis novae-hollandiae* Kinberg, *Lysidice collaris* Grube. Captured in the holdfasts of *Ecklonia*: *Syllis closterobranchia* Schmar. var. *kinbergiana* Augener, *Syllis zonata* (Hasw.), *Platynereis dumerilii* (Aud. and M. Edw.), *Audouinia anchylochaeta* (Schmarda).

GEPHYREA:

**Phymosoma japonica* Grube. Not on rocks, but burrowed into them.

BRYOZOA:

**Membranipora membranacea* Lamk., **Schizoporella biturrita* Hincks. Other bryozoans unidentified.

CRUSTACEA:

Balanus imperator Darwin, **Tetraclita radiata* Blainville, *Balanus nigrescens* Lamk., *Rhynchocinetes rugulosus* (Stimp.), **Hippolyte australiensis* (Stimp.), **Alope australis* (Baker). Amphipoda as follows: *Elasmopus crassimanus* (Miers), *Elasmopus diemenensis* Hasw., *Elasmopus subcarinatus* Hasw., *Paramoera megalophthalma* (Hasw.). Copepod: Sub-order Haroacticoida. Crabs: *Eriphia norfolcensis* McCulloch, *Halicarcinus varius* (Dana), *Actaea tomentosa* (H. M. Edw.), *Naxia tumida* (Dana), *Menaethius monocerus* (Latr.), *Plagusia capensis* de Haan, *Eupagurus lacertosus* var. *nana* Henderson.

INSECTA:

Chunio pacificus Edw., *Limonia marina* (Sk.), Ephydrid, larval stage, Chironomid larvae (numerous).

ECHINODERMATA:

**Heliocidaris erythrogramma* (Valenc.), *Heliocidaris tuberculata* Lamk., **Patiriella calcar* (Lamk.), *Centrostephanus rodgersii* A. Agass., **Coscinasterias calamaria* (Gray).

MOLLUSCA:

Lamellibranchiata: *Pinctada perviridis* (Reeve), *Arca fasciata* Reeve (not on the surface of the rock, but in it), *Reniella spongiarum* (Lamk.) (in sponge), **Cardita excavata* Desh., *Venerupis crenata* Lamk. Amphineura: *Onithochiton quercinus* (Gould), *Poneroplax paeteliana* (Thiele), *Lorica volvox* Reeve. Gasteropoda: *Patelloida alticostata complanata* Ired., *Montfortula conoidea* (Reeve), *Dicathais orbita* (Gmelin), *Patellanax squamiferus* (Reeve), *Patella perplexa* (Pilsbry), **Floraconus papilliferus* (Sowerby), *Floraconus aplustre* (Reeve), *Casella atromarginata* Cuvier, *Turbo militaris*

* The names marked with an asterisk denote the fact that the animals are found also under stones in "Stony Bay".

(Reeve), *Charonia rubicunda* (Perry), *Hydatina physis* (Linné), *Reticunassa paupera* (Gould), *Ravitrona caputserpentis* (Linné), *Mimelenchus ventricosus* (Swainson), **Agnewia tritoniformis* (Blainville), *Radiacmaea insignis* (Menke), *Sabia foliacea* (Quoy & Gaim.), *Tugali parmophoidea* (Quoy & Gaim.), *Cymatilesta spengleri* (Perry), **Dolabrifera brazieri* Sowerby, **Tethys angasi* (Sowerby), *Phasianotrochus eximius* (Perry), *Bullinula lineata* (Gray), **Bellastraea sirius* (Gould), **Bellastraea kesteveni* Ired., *Eligidion audax* Ired., *Astelena scitula* (Adams), *Phasianella virgo* Angas.

Addendum to the list of gasteropods from the fauna on the upper sides of rocks.

The following species live on the thalli of the algae on the rocks. Through the kindness of Mr. C. F. Laseron and his son John, both systematic collectors of tiny molluscs, lists of the species obtained at Long Reef and valuable notes on habitats were also made available, and the author is grateful for the help given.

Gasteropoda on algae:

Cingulina diaphana Verco, *Cingulina* sp., *Anabathron contabulatum* Frauenfeld, *Zafra atkinsoni* (Ten.-Woods), *Triphora labiata* Adams, *Triphora ampulla* Hedley, *Amphithalamus jacksoni* Brazier, *Gabrielona* sp., *Marginella angasi* Crosse, *Marginella nympha* Brazier, *Diala* sp., *Melanella* sp., *Oscilla tasmanica* (Ten.-Woods), *Haurakia descrepans* (Tate & May), *Microdiscula charopa* (Tate), *Orbitestella* spp., *Omalogyra* spp., *Notosetia* sp., *Schismope atkinsoni* (Ten.-Woods).

Ascidiacea:

Pyura praeputialis (Stimp.). **Small round compound ascidians.*

(*b*). *Lower Surfaces of Rocks and in Rocks.*

This fauna is a very distinctive one, and is found under the larger boulders in the seaward part of "Stony Bay" and in the boulder area which extends round the outer edge of the rock-platforms or in dark pockets and pools of the main rock-platform. The conspicuous species, on account of their size, are echinoderms and chitons, and in addition to these, the surfaces of the rocks are frequently covered by encrustations of small tube-building worms. Various types of crustaceans—amphipods, snapping prawns and isopods—are numerous and move rapidly off the rocks turned over for inspection. Nudibranchs and other gasteropods are common and flatworms and nemerteans crawl over the rock surfaces or creep into crevices among the tubes of polychaetes. Brittle-stars also are common and occasional feather-stars are found. Bryozoans, anemones and ascidians (simple and compound) are under almost every stone. The indicator species chosen are the sea-urchin, *Heliocidaris erythrogramma*, and the chiton, *Ischnoradsia australis australis*.

(i). Heliocidaris–Ischnoradsia *Association*.—When larger rocks—with a free circulation of water under them—are turned over, two large species immediately attract attention: the sea-urchin, *Heliocidaris erythrogramma*, and the chiton, *Ischnoradsia australis australis*. Plate x, figure 27, shows the under side of a rock, housing a typical fragment of this animal association. All the chitons in the picture belong to the species *Ischnoradsia australis australis*, the sea-urchin is *Heliocidaris erythrogramma*, the brittle-star belongs to the species *Ophiarachnella ramsayi* and the white patches on the rock are the tubes of the tiny worm *Spirorbis*.

The two most plentiful tube-worms occurring on the lower sides of rocks are the small *Spirorbis*, mentioned above, and *Salmacina australis* with its delicate, fine, white tubes. A splendid growth of *Salmacina* which has completely filled several holes formerly occupied by sea-urchins, is seen in Plate xi, figure 32. The tubes tend to grow together in bunches of ten or so, and to form the finger-like projections seen in the photograph. The holes in the rock are caused by *Heliocidaris*, though the occupants are not as clearly defined in the photograph as they might be. The small, rounded tubes, lying flat on the rock face, are those of *Spirorbis*.

Rocks from this part of the reef which rest on sand have a slightly different fauna, consisting mostly of brittle-stars, chitons and spirorbids. The sea-urchins are absent. Plate xi, figure 33, shows the lower surface of a rock which was resting on sand. Two species of brittle-stars are illustrated and two sea-stars, *Coscinasterias* and *Allostichaster*. Several chitons are also present and a small specimen of the "elephant snail", *Scutus antipodes*. The latter is frequently encountered under rocks, both those resting on sandy bottom and those beneath which water circulates freely. *Spirorbis* covers the areas of rock which appear white in the illustration.

Many ascidians appear in the sub-littoral fringe and the species occurring below rocks are, as would be expected, more delicate in structure than the tough *Pyura praeputialis* from the upper sides of rocks.

The commonest crab is *Pilumnus rufopunctatus*, frequently looking like the rock which houses it. Other crabs include *Paraxanthias elegans* (= *P. atromanus* (Hasw.)) and *Ozius truncatus*. Many isopods, amphipods and "snapping prawns" (*Crangon*) live among the rocks or shelter under them during low tides. Hermit crabs, particularly *Eupagurus lacertosus* var. *nana*, are exceedingly common in every nook and cranny of the rocks.

Many molluscs live on the lower sides of the rocks and are listed below. Sponges are present beneath those rocks where water circulates. The following list contains the common species found in this association:

Animals from the Lower Surfaces of Rocks in the Sub-littoral Fringe.

PORIFERA:

Chalina sp., *Gellius raphiophora* var. Other sponges of the bread-crumb type.

COELENTERATA:

Clavularia rosea Studer, *Cylicia quinaria* Ten.-Woods, *Bunoides* sp.

TURBELLARIA:

Trippylocelis typica Hasw., *Leptoplana australis* (Laidlaw), *Diplosolenia johnstoni* Hasw.

POLYCHAETA:

In addition to the polychaetes marked in the list above with an asterisk are the following species, on the lower side of rocks at low water mark:

Pionosyllis (near *comosa* Grube), *Salmacina australis* Hasw., *Glycera opisthobranchiata* Marenzeller, *Eurythoë complanata* Dallas.

BRYOZOA:

See list given above for lower level of littoral.

CRUSTACEA:

Tetraclita radiata Blain. Amphipods (see lists for other parts of the reef). *Cancellus typus* M.-Edw., *Eupagurus* (two species already listed), *Paguristes squamosus* McCulloch, *Crangon villosus* (Olivier). Prawns (listed as roving forms), *Paratanais ignotus* Chilton. Sphaeromidae (Eubranchiate), *Betaeus* sp. (small species, red with longitudinal white stripe), *Lysiosquilla perpasta* Hale. Crabs listed as belonging to the lower littoral belong also to this group.

MOLLUSCA:

In addition to molluscs marked with an asterisk in the preceding list (pp. 244-245) the following forms occur:

Gasteropoda: *Erronea nimiserrans* Ired., *Euplica versicolor* (Sowerby), *Doris arbutus* Angas, *Flabellina ornata* Angas, *Aeolis macleayi* Angas, *Dendrodoris carneola* (Angas), *Dendrodoris davisi* Allan, *Dendrodoris melaena* Allan, *Oscanius* n. sp., *Rostanga arbutus* (Angas), *Pleurobranchus punctatus* Q. & G., *Haliotus ruber* Leach (olim *H. naevosum*), *Bellastraea sirius* (Gould), *Bellastraea kesteveni* Ired., *Pyrene australis* Gaskoin, *Herpetopoma aspersa* Philippi, *Lepsiella botanica* Hedley, *Oscanius hilli* Hedley, *Sophismalepas nigrita* (Sowerby), *Scutus antipodes* Montfort, *Dolabrifera brazieri* Sowerby, *Tethys angasi* (Sowb.), *Vicimitra rhodia* Reeve.

The following list of tiny gasteropods was kindly made available by Mr. C. F. Laseron and should be added to those given above:

Merelina strangei (Brazier), *Merelina* sp. (? *M. seminodosa*), *Anabathron contabulatum* Frauenfeld, *Scrobs scrobiculator* (Watson), *Scrobs* sp., *Schismope atkinsoni* (Ten.-Woods), *Scissurella* sp.

Amphineura: *Rhyssoplax jugosa* (Gould), *Rhyssoplax coxi* (Pilsbry), *Rhyssoplax vauclusensis* (Hedley), *Terenochiton badius* (Hedley & Hull), *Parachiton puppis* Hull, *Ischnochiton elongatus crispus* (Reeve), *Ischnochiton examinandus examinandus* Hull, *Ischnochiton versicolor versicolor* (Sowerby), *Ischnoradsia australis australis* (Sowerb.), *Heterozona fruticosa* (Gould), *Paricoplax crocina* (Reeve), *Loricella angasi* (H. Adams), *Delicatoplax translucens* (Hedley & Hull), *Notoplax costata* (H. Adams & Angas), *Lorica volvox* (Reeve), *Mucrosquama carnosa* (Angas).

ECHINODERMATA:

Asteroidea: *Coscinasterias calamaria* (Gray), *Allostichaster polyplax* (M. & T.), *Patiriella calcar* (Lamk.), *Patiriella gunnii* (Gray), *Asterina inopinata* Livingstone. Ophiuroidea: *Ophiarachnella ramsayi* (Bell), *Macrophiothrix lampra* H. L. Clark, *Placophiothrix spongicola* (Stimp.), *Ophiocoma pulchra* (H. L. Clark), *Ophionereis schayeri* (M. & T.), *Ophiactis resiliens* Lyman, *Amphipholis squamata* (Delle Chiaje.). Echinoidea: *Heliocidaris erythrogramma* (Valenc.), *Centrostephanus rodgersii* (A. Agassiz), *Phyllacanthus parvispinus* Ten.-Woods. Holothuroidea: Sub-family Synallactinae. Crinoidea: *Comanthes trichoptera* (J. Mueller), *Compsometra loveni* (Bell).

ASCIDIACEA:

Ascidia incerta Herdman, *Styela personata* (Herdman), *Polycitor* sp. (? *P. vitreus* Sars), *Pyura* sp. (? *P. squamata*), *Pyura complanata* (Herdman), *Microcosmus draschii* (Herdman).

2. *Animals of the Gravelly-sand Substratum.*

This animal community belongs to the bivalve-worm type (Clements and Shelford, 1939), since its dominant forms are all sand-burrowers, feeding on detritus or preying on the animals of their immediate surroundings. Though their habitat may be exposed for a short period during low tides, they are always surrounded by a considerable amount of moisture retained in the sand, and cannot be regarded as undergoing rhythmic exposure to the air, as do the members of the community which inhabits the littoral on the neighbouring rocky reefs. This bivalve-worm community is, therefore, the upper fringe of a community found usually in the true sub-littoral area, but, owing to the special nature of the bottom in "Stony Bay", it has been able to extend upwards above the limits of the low spring tides. It differs from the true sub-littoral community which occurs seawards of the reef, a fact which perhaps may be accounted for by the shallowness of the small pockets of sand forming the substratum, for it exhibits a "fading out" effect. Although classified as a bivalve-worm community, the number of live bivalves encountered is very small and no forms of mollusc can be cited as indicator species for the community. Neighbouring sand beaches have for their indicator species the bivalve, *Donax deltoides*, and the polychaete, *Onuphis teres*. *Donax* has not, however, been encountered alive in "Stony Bay". The live bivalves present are small in size. Dead shells of the larger *Codakia rugifera* are, however, frequently encountered, but this species has not been taken alive by the author.* As many as eight empty shells of this *Codakia* occur to the square foot, and as the shell is a large, heavy one, it seems reasonable to suppose that the habitat would be close at hand, as currents are rarely strong enough in the "Bay" to move these shells any distance. Despite the small number of bivalves present, it is justifiable to classify the community as a bivalve-worm one because other forms of animals usually associated with such a community are present as dominant forms. A polychaete, *Diopatra dentata*, is present in great numbers. The sipunculid, *Phymosoma japonica*, is also a dominant form and occurs together with the holothurian, *Leptosynapta dolabrifera*.

There appears to be only one association in the sandy substratum at Long Reef. The indicator species chosen to designate it are *Diopatra dentata* and *Leptosynapta dolabrifera*.

(i). *The* Diopatra–Leptosynapta *Association*.—In "Stony Bay" the animals of this association occur in the scattered patches of sand, often not more than a few square inches in extent and frequently not more than nine inches to one foot in depth (Pl. xi, fig. 29).

Quadrating was attempted in this area of the reef by means of a frame one foot square. The use of a small frame was necessary owing to the size of the sand patches. The method employed was to dig up both sand and boulders in the area to as great a depth as possible, carefully removing those animals which were clinging to the rocks themselves and separating them from those sieved from the sand. The sand was passed through increasingly fine sieves and the sievings were examined and the animals counted. It was frequently found impossible to dig up the sand to a depth greater than nine inches owing to the closeness with which the boulders were packed together and the impossibility of moving them in the time available between tides. The number of animals at a depth of nine inches was not very great and by the time the one foot level was reached was becoming even less, being limited to a few worms. Each quadrat carried out in this way took from one to one and a half hours to complete, so it was possible to complete only one or two during each low tide. The average numbers of the various species are given in the following table:

* Mr. T. Iredale of the Australian Museum informs me that these bivalves do live buried in the coarse, gravelly-sand here.

Average Numbers of Common Species in the Diopatra-Leptosynapta *Association.*
(Obtained by analysing the results of fifteen quadrats.)

Name.	Number per Square Foot.	Remarks.
Polychaeta.		
Diopatra dentata Kinberg.	30-40	Probably plankton feeders.
Clymene integrinatus Haswell.	2-3	
Psammolyce antipoda Schmarda.	Common but not found in every quadrat.	
? *Audouinia anchylochaeta* Schmarda.	Common but not found in every quadrat.	Juveniles.
Gephyrea.		
Phymosoma japonica Grube.	5-6	
Nemertinea.		
Gorgonorhynchus repens Dakin.	Occasional.	Breeding Oct.-Dec.
Nemerteans 1. black and white. 2. purply-black. 3. green.	Occasional.	More generally found under rocks.
Crustacea.		
Axiopsis (*Axiopsis*) *australiensis* de Man. *Axiopsis* sp.	5	
Amphipods (not identified).	Common.	
Echinodermata.		
Holothuroidea:		
Leptosynapta dolabrifera (Stimpson).	6	
Ophiuroidea:		
Amphiura constricta Lyman. *Amphiura catephes* H. L. Clark. *Amphiura multiremula* H. L. Clark.	0·25	These are very small in size and are obtained only by sieving.
Mollusca.		
Gasteropoda:		
Nassarius particeps Hedley.	1-2 (6-7)	6-7 are found in the breeding season (September). At other times there are 1-2.
Crosseola concinna (Angas).	Rare.	
Notocochlis cothurnata Iredale.	Rare.	
Lamellibranchiata:		
Zemysia zelandica (Gray).	Rare.	
Codakia rugifera Reeve.	8	Dead shells.
Codakia bella (Conrad).	Common.	
Enteropneusta.		
Balanoglossus australiensis (Hill).	1	In sand, along with *Gorgonorhynchus repens*.

The most conspicuous animal in the *Diopatra–Leptosynapta* Association is the eunicid worm, *Diopatra dentata*, not only on account of its numbers, but also on account of the large, tough tubes it builds. These tubes are plastered with pieces of shell, sand, tiny stones and other debris and project above the bottom for about three inches. They are usually found in clumps of eight or nine (Pl. xi, fig. 28). During low tides the worm retires to the depths of its tube, which then collapses somewhat, and lies sideways on the sand. At high tide, however, the tube stands upright, the worm's head projects, tentacles are extended to breathe and to collect food. As indicated in the table, as many as forty tubes may be found in one square foot. At first sight this number may seem to be too high, but when the sand is sieved a considerable number of tubes is unearthed from between the rocks and sand which obscure them. Although the feeding

of the worms is carried out above the bottom, when the tide is high, a fact which would associate them with surface-dwellers, they have been included in this association because they have specially well-developed branchiae, correlated with which is the fact that much time is spent withdrawn into the tube, and the worms have to be able to extract oxygen from the limited amount in the water held in their tubes or in the surrounding sand. Waste products from the metabolism are also released into the sand during low tides so that these worms must, therefore, be considered as a definite biotic factor in the community.

The holothurian, *Leptosynapta dolabrifera*, is the other indicator species of the association, five or six individuals occurring in each square foot. They burrow through the sand and are found in close proximity to the gephyrean, *Phymosoma japonica*. The gut of *Leptosynapta* is often filled with sand and debris which seems to indicate that this is the method of obtaining food—a detritus feeder. *Phymosoma* is almost as common as *Leptosynapta* and at certain seasons (from November to March) is certainly more numerous than at other times.

The gasteropod, *Nassarius particeps*, is occasionally found in large numbers (6–7 per square foot), but this was during the breeding season in September when numerous individuals were seen copulating in the water in the small pools of "Stony Bay". At other times one or two was the average number of *Nassarius* per square foot.

Among other inhabitants of the association are two "nipper prawns", *Axiopsis australiensis* and *Axiopsis* sp. At night stray individuals may be encountered on the surface, moving about and apparently feeding.

Molluscs appear very frequently, as shown by the numbers of dead shells of *Codakia rugifera* which lie in the sand in the vicinity. A small bivalve, *Zemysia zelandica*, is fairly common in the sand, while two other molluscs, *Notocochlis cothurnata* and *Crosseola concinna* are, on rare occasions, found alive.

The enteropneust, *Balanoglossus australiensis*, is found together with occasional specimens of the peculiar nemertean, *Gorgonorhynchus repens*, burrowing in the sand, closely associated with the gephyrean (*Phymosoma japonica*), but whereas *Phymosoma* is still found below the limit of the average low spring tides, the two former species occur only in the areas of the sand in "Stony Bay" which lie above this level. *Gorgonorhynchus* and *Balanoglossus* are by no means rare, occurring, on the average, about once in every square foot of sand. In the deeper layers of sand (i.e., below six inches) the maldanid worm, *Clymene integrinatus*, is often found, both in the inshore areas and out to sea. This worm or a related species is the one also occurring in the sand imprisoned in the holdfasts of the "dwarf kelp", *Ecklonia*, and in *Phyllospora*, when these algae are cast up after storms.

Several species of nemertean, apart from *Gorgonorhynchus*, are found in the sand. They are as yet unidentified. By far the most numerous animals in the association are the amphipods which occur in hundreds in the sand or hopping over its surface.

At low tide, many animals which otherwise would be roaming over the surface, take shelter by burrowing in the sand and among the rocks. In this group are included the octopuses which retire to definite made "nests". They include *Octopus maculosus* and *O. cyaneus*. Their numbers are hard to determine, since local fishermen wage a continual war on them, as they are much prized as bait, and systematic collection goes on during practically every low tide. They are, nevertheless, still quite common, so their numbers must be high in the first place. Also sheltering in similar holes are eels, *Verdithorax prasinus*, which are met with only occasionally.

Frequently buried in the sand are brittle-stars of the genus *Amphiura*. Three species are recorded by Clark (1938), from the reef: *Amphiura constricta*, *A. catepes* and *A. multiremula*. They are found fairly frequently, although no definite numbers are given for the individual species in the table above. One amphiuran occurs, on the average, in one quadrat in four. They are of an extremely small size, so that a casual observer misses them.

During night-time observations of the reef-dwellers, it was found that, even during low tides, some of the animals which, by day, lived completely buried in the sand, came up to the surface and moved about. The absence of strong light and the dampness of

the night air probably allowed them to do so. Among the animals which prowled thus were the nemertean, *Gorgonorhynchus*, and the "nipper prawn", *Axiopsis*. The tube-worms, *Diopatra*, which by day retired during low tides to the depths of their tubes, leaving them flaccid and lying along the bottom, were found by night to remain near the mouth of their tubes which thus projected upright above the bottom. Sometimes the head of the worm was found projecting from the tube, but was withdrawn at our approach.

3. *Roving Forms.*

(*a*). *Note on the Fishes at Long Reef.*

Certain fish occurring on the reef are found there even when the tide recedes and leaves their habitat above low water level, and they exist till the next high tide by hiding under stones or by remaining in tiny pools. Some of them like the "blennies" or the "Tommy Fish", *Limnicthys*, can wriggle or skip over the rocks between pools. Fish with these habits have been classified as belonging to the regular fauna of the reef and are described in the appropriate section of this paper. Other fish, however, may be classified as visitors, since they follow the tide as it rises and falls. These are never found far from reefs on the coast and thus form a kind of "ecotone" between the benthos of the littoral and the nekton of the sub-littoral part of the shore. A table of these forms is given, together with a few remarks on their habitats and an idea of their frequency. No attempt has been made to provide a complete list of fish from Long Reef. Only those forms seen or taken by the author are included.

Name.	Remarks.
Centropogon australis (Shaw). "Fortesque."	Shallow water on edge of reef; commonly caught by fishermen.
Petraites fasciatus (Macleay). "Weed Fish."	Lives among *Sargassum*; moves with the tide. Common.
Epinephelus dameli (Gunther). "Black Rock Cod."	Outer edge of the reef; also in pools. Common.
Crinodus lophodon (Gunther). "Rock Cale."	In pools among *Sargassum* and outer edge of the reef. Fairly common.
Parma microlepis Gunther. "White Ear."	Among weeds on edge of reef; in "Stony Bay". Fairly common.
Brachaluteres fidens Whitley. "Green Pigmy Leather Jacket."	Darts about among weed on the edge of reef in "Stony Bay". Common.
Spheroides hamiltoni Richardson. "Common Toado."	Moves with the tide. Common.
Ruboralga jacksoniensis (Steindachner).	Caught off rocks by fishermen. Common.
Acanthistius serratus (Cuv. & Val.). "Wirrah."	Outer edge of the reef. Fairly common.
Eggs of *Heterodontus portusjacksoni* (Meyer). "Port Jackson Shark."	Entangled in the seaweeds in deeper water. Occasional.
Notesthes robusta Gunther. "Bullrout."	In shallow water and pools at the edge of the reef. Common.

VIII. Discussion.

The animal associations found at Long Reef are, for the most part, similar to those described from rock-platforms in other localities, but there are one or two important differences, e.g., the presence of a number of forms normally found in quiet harbour waters in addition to the regular inhabitants of coastal habitats.

(*a*). *The Rocky Reef Communities.*

The *Pyura praeputialis* (ascidian) Association, so characteristic of the sub-littoral fringe on other headlands, is only feebly developed, probably owing to the flatness of the rocks and the degree of shelter from wave action.

In and above the sub-littoral fringe level, there is a well-developed barnacle association—in the lower parts, *Balanus nigrescens* is found, while slightly higher up *Tetraclita rosea* covers the rocks. At a still higher level, the tiny barnacle, *Chamaesipho columna*, occurs in thousands.

Above the barnacle-covered area is an association where molluscs are the dominant type—limpets, false-limpets and, above all, periwinkles are found in areas where there is sufficient algal food.

Highest on the rock-platforms a littorinid association is generally found, but this association does not reach full development on the particular area studied at Long Reef, though it is well developed on neighbouring parts of the reef.

The above communities are found on the upper surfaces of rocks, but they are paralleled by those from the lower surfaces. The ascidian community which corresponds to the *Pyura* one, mentioned above, is characterized by the large, spiculate *Microcosmus draschii*, which occurs under almost every stone in the sub-littoral fringe.

Barnacle species from sheltered places among or beneath the rocks include *Balanus imperator* (occurring at about the same level as *B. nigrescens*), and *Tetraclita radiata* and *T. purpurascens*, which are found above *B. imperator* in the littoral area of "Stony Bay".

Many tiny Mollusca live beneath the rocks and have been listed above. They correspond to the limpet and other molluscs of the upper sides of rocks. There is, of course, no littorinid association on the lower surfaces of the boulders, but in the supra-littoral there is a small area where marine and terrestrial animals occur together underneath the stones, which lie on the sandy beach. This special community is described on page 231.

There is a strong resemblance between the inhabitants listed from the lower surfaces of boulders at Long Reef and those assigned to rock-pool communities by Harvey Johnston (1917).

(*b*). *The Gravelly-sand Communities.*

Fragments of sandy substratum occur among the boulders of "Stony Bay" and a small, modified, sand-dwelling animal community has been developed there. It represents the upper fringe of the community found as a rule in the true sub-littoral of the seashore.

One interesting point that has emerged from the investigation is the fact that, both among the plants and the animals, certain forms usually found flourishing in quieter harbour waters, occur in scattered patches on the area studied at Long Reef. Outstanding examples of such forms are the seaweeds *Zostera* and a species of *Sargassum*, while prominent animals are the weed-prawn, *Leander intermedius*, and certain species of amphipods. The degree of shelter from the wash of the surf offered at Long Reef would appear to be better than it is on the other ocean rock-platforms in the locality and this would account for the wide variety of animals found there.

IX. Summary.

An attempt has been made in this paper to describe the plant and animal communities of a small area of a rock-platform on the sea coast at Long Reef, near Sydney, New South Wales.

The geological structure of the area is described and other environmental factors are considered.

A fairly detailed account of the distribution of the plants is given, since they play an important part in providing food and shelter for the animals.

Two distinct types of animal associations occur side by side in some parts of the area, and form an interesting mosaic of fragments of animal associations, i.e., those forms which inhabit a sandy bottom and those which live attached to rocks.

Lists of the common animals for the different levels of the reef and for the different habitats are given as well as short descriptions of the animal associations. A number of forms usually associated with harbour faunas is found in the area, since the shelter offered from waves is considerable owing to the situation and geological conformation of the reef.

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EXPLANATION OF PLATES VII-XI.

Plate vii.

Ecological map showing the geology of the area and the names used in this paper for the various parts of the reef.

Plate viia.

Map showing the heights of the various parts of the reef above zero tide level and the low water marks for tides. Heights quoted represent the minimum for the surrounding rocks. The distribution of the plants is also shown.

Plate viii.

Fig. 1.—An area of the "Stony Bay" region, showing the stones and small boulders which cover the floor of practically the whole of the "Bay". This area lies in the littoral region of the reef.

Fig. 2.—The sub-littoral fringe in "Stony Bay". The boulders are very much larger than those of the inshore or littoral part. The nature of the algal "mat" is well illustrated. "Barnacle Point" appears on the right hand side in the middle distance. Photo, A. Musgrave.

Fig. 3.—A small area of the Hormosiretum where the alga forms a dense mat (in a pool in a crevice). The large mollusc is *Ninella torquata*. The light patches on the rock on the edge of the crevice are growths of the coralline, *Lithothamnion*. Photo, Anne Sanderson.

Fig. 4.—An area on "Chocolate Shale Point" where the *Hormosira* grows in a scattered manner. This area is completely drained during low tides. Photo, W. J. Dakin.

Fig. 5.—An area of "Grey Shale Point" on an outcrop of argillaceous grey shale where the surface of the rock is covered by a growth of *Pylaiella littoralis*. A good growth may be seen between the knife and the jar and several molluscs, in the area, are also coated by it. The molluscs are *Siphonaria scabra* and *Morula marginalba*.

Fig. 6.—An area towards the outer edge of "Chocolate Shale Point" where there is a zone of "overlap" between the *Hormosira* and the *Corallina* communities. Photograph taken from the seaward side of the reef.

Fig. 7.—The shallow south-western end of the pool on "Grey Shale Point" during a low tide. The nature of the habitat is similar to that among the boulders in "Stony Bay" and the animal communities are almost identical. Algae from this pool include chiefly *Hormosira* with a limited amount of *Sargassum*.

Fig. 8.—The deeper end of the pool on "Grey Shale Point", showing "Stony Bay" and "T-Reef" in the middle distance. The photograph was taken during a low tide and the weeds, showing on the top of the water, are a species of *Sargassum*. Other algae present include *Phyllospora comosa*, *Amphiroa anceps* and *Corallina*. The fauna of this pool is similar to that of the lowest parts of the rocky reef.

Plate ix.

Fig. 9.—A cluster of *Melancrita melanotragus* availing itself of the shelter afforded by a shallow crevice in the upper littoral area. Photo, Anne Sanderson.

Fig. 10.—An area of rock covered by *Chamaesipho columna* and *Cellana tramoserica*. The tiny barnacles cover the rock surface closely and exclude other animals almost entirely from any area where they occur. Photo, Gwen Burns.

Fig. 11.—A close view of the top of "Barnacle Point", showing *Tetraclita rosea*. On the left hand side of the photograph, in the middle distance, is a specimen of the "surf barnacle", *Catophragmus polymerus*, which forms an important community at Harbord, but which is rare on this part of Long Reef. Photo, Gwen Burns.

Fig. 12.—The outer edge of "Island One" in the littoral area. This part is exposed to the breaking surf at all times and its chief inhabitants are the barnacle, *Balanus nigrescens*, and the chiton, *Onithochiton quercinus*. *Onithochiton* occupies the small holes, seen in the shale, and has, in all probability, excavated them.

Fig. 13.—A cluster of limpets, *Cellana tramoserica*, and periwinkles, *Austrocochlea*, sheltering in a crevice during the low tide. At night or during high tides, they move actively about, feeding on the algae. Photo, W. J. Dakin.

Fig. 14.—A view of "T-Reef" during a low spring tide. The rocks are covered with *Sargassum* and there is a well-developed, sub-littoral fringe fauna and flora on the rocks. Note the scattered ascidians on the rocks of the foreground.

Fig. 15.—A small part of the flat rock-platform of "Chocolate Shale Point" where *Galeolaria caespitosa* tubes are scattered on the rock at intervals, and cannot form the "coral-like" growths such as are shown in Figure 17. Photo, Gwen Burns.

Fig. 16.—Where vertical rock faces offer in the lower littoral area, a thick growth of *Galeolaria* is found. Photo, Gwen Burns.

Fig. 17.—The outer edge of "Chocolate Shale Point", showing scattered individuals of the ascidian, *Pyura praeputialis* (the little, dark, wart-like humps on the rock in the foreground). *Pyura*, like *Galeolaria*, seems to reach its full development on steep slopes of rock.

Fig. 18.—A thick clump of *Pyura praeputialis*, round the edge of a boulder in the sub-littoral fringe. These clumps house a number of worms, chitons and nematodes. Photo, W. J. Dakin.

Plate x.

Fig. 19.—A pot-hole in the littoral area. On the flat rock, in the lower right hand corner of the photograph, are six specimens of the pulmonate, *Siphonaria scabra*. In the pool and on the seaweeds are several specimens of *Austrocochlea*. Photo, W. J. Dakin.

Fig. 20.—The lower surface of a stone from the littoral area of "Stony Bay". The tiny, rounded worm tube is a spirorbid, while the larger solitary one is that of *Vermilia rosea*. The pleurobranch is *Pleurobranchus punctatus* and near it is a batch of eggs of the cone, *Floraconus*. The *Corallina* on the upper side of the rock is projecting from the edge of the top right hand corner of the stone. Photo, Gwen Burns.

Fig. 21.—The Zosteretum in the pool which lies at the inshore edge of "Chocolate Shale Point". Mixed in with the *Zostera nana* is a little *Hormosira*.

Fig. 22.—The sub-littoral fringe on "Grey Shale Point", showing the algal "mat". The prominent algae are *Corallina* and *Sargassum*. In the large pools, left by the tide, are isolated plants of *Phyllospora*, *Ecklonia*, and a feathery form of *Sargassum*. This is the area frequented by the small kelp fly, *Clunio pacificus*. Photo, Anne Sanderson.

Fig. 23.—A general view of the area studied, taken from the western end, during a specially low spring tide. The dark area, on the edge nearest the camera, is covered by a growth of *Sargassum*. This part of the reef is an especially fine collecting ground.

Fig. 24.—The sub-littoral fringe of "Stony Bay" during a moderately low spring tide. *Sargassum* is the weed, exposed on the rocks, and it is inhabited by numerous prawns, amphipods, and kelp shells.

Fig. 25.—The outer region of "Stony Bay", showing the extent to which *Phyllospora* is normally exposed, i.e., it lies flush with the water. In the background the fringe of *Sargassum* round the "Bay" may be seen.

Fig. 26.—The purple sponge, *Chalina* sp., encrusts the vertical faces of the rocks or is found in shaded pot-holes. At lower levels of the sub-littoral, in deeper water, it encrusts the upper sides of rocks. Photo, A. Musgrave.

Fig. 27.—The lower side of a rock from the sub-littoral fringe area of "Stony Bay". Water circulates freely beneath this stone during all but the lowest tides.

Plate xi.

Fig. 28.—A few square yards of "Stony Bay" which show the sand and stones "mosaic". The collector is indicating several tubes of *Diopatra dentata*, a worm which often has its tube camouflaged by algae or debris.

Fig. 29.—The "mosaic area" of sand and boulders in "Stony Bay". Light patches, between stones, indicate the sizes of the sand components of the "mosaic".

Fig. 30.—The sub-littoral fringe of "Grey Shale Point" during an exceptionally low spring tide. The pot-holes house several specimens of the sea-urchin, *Heliocidaris erythrogramma*, with occasional specimens of the rarer one, *Strongylocentrotus tuberculatus*. The chiton, *Poneroplax paeteliana*, is also found in such holes.

Fig. 31.—A crevice filled with water in the littoral area of the reef. A specimen of *Patiriella exigua* may be seen and the anemone, *Oulactis mucosa*, in an expanded position. The latter animal is disguised with stones and debris. Photo, Gwen Burns.

Fig. 32.—The lower surface of a rock from the sub-littoral fringe on the western edge of the reef. The fine, white worm tube is *Salmacina australis* which, in this case, has filled a hole bored in the rock by a sea-urchin. Two other similar holes house urchins which cannot, however, be seen clearly. Tubes of *Spirorbis* are also scattered over the rock. Photo, Gwen Burns.

Fig. 33.—The lower surface of a rock from the sub-littoral fringe of "Stony Bay". The rock was resting on sand and the chief inhabitants are, therefore, ophiuroids instead of sea-urchins. Sea-stars are also prominent, the largest being *Coscinasterias calamaria*. A small specimen of the elephant snail, *Scutus antipodes*, may be seen below the sea-star and two species of worm tubes. The chiton is *Ischnoradsia australis australis*.

Fig. 34.—A water-filled rock pool in the lower littoral. The common, 8-rayed sea-star, *Patiriella calcar*, is seen in numbers clinging to the floor of the pool. Photo, A. Musgrave.

Fig. 35.—Among the chitons, *Sypharochiton septentriones* climbs highest on the rocks. It clings, in sheltered spots, to the upper sides of rocks in the littoral part of the reef. In the illustration it is associated with *Cellana tramoserica* and *Galeolaria caespitosa*. Photo, A. Musgrave.

Fig. 36.—The *Phyllospora* community of algae exposed by an exceptionally low tide. The surfaces of the rocks between the holdfasts of *Phyllospora comosa* are coated with the coralline, *Lithothamnion*. In the foreground on the right hand side, *Corallina* carpets the rocks. Numerous other small forms of algae may be seen in the foreground. Photo, A. Musgrave.